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THE

EVOLUTION OF MAN:

A POPULAR EXPOSITION

OF THE

PRINCIPAL POINTS OF HUMAN ONTOGENY AND PHYLOGENY.

FROM THE GERMAN OF

ERNST HAECKEL,

PROFESSOR IN THE UNIVERSITY OF JENA,

AUTHOR OF "THE HISTORY OF CREATION," ETC.

IN TWO VOLUMES.

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THE EVOLUTION OF MAN.

CHAPTER XV.

THE DURATION OF HUMAN TRIBAL HISTORY.

Comparison of Ontogenetic and Phylogenetic Periods of Time.—Duration of Germ-history in Man and in Different Animals.—Extreme Brevity of the Latter in Comparison with the Immeasurable Long Periods of Tribal History.—Relation of this Rapid Ontogenetic Modification to the Slow Phylogenetic Metamorphosis.—Estimate of the Past Duration of the Organic World, founded on the Relative Thickness of Sedimentary Rock-strata, or Neptunian Formations.—The Five Main Divisions in the Latter: I. Primordial, or Archilithic Epoch. II. Primary, or Palæolithic Epoch. III. Secondary, or Mesolithic Epoch. IV. Tertiary, or Cænolithic Epoch. V. Quaternary, or Anthropolithic Epoch.—The Relative Duration of the Five Epochs.—The Results of Comparative Philology as Explaining the Phylogeny of Species.—The Inter-relations of the Main Stems and Branches of the Indo-Germanic Languages are Analogous to the Inter-relations of the Main Stems and Branches of the Vertebrate Tribe.—The Parent Forms in both Cases are Extinct.—The Most Important Stages among the Human Ancestral Forms.—Monera originated by Spontaneous Generation.—Necessity of Spontaneous Generation.

"In vain as yet has it been attempted to draw an exact line of demarcation between historic and prehistoric times; the origin of man and the period of his first appearance pass back into indefinable time; the so-called archaic age cannot be sharply distinguished from the present age. This is the fate of all geological, as of all historical periods. The periods which we distinguish are, therefore, more or less arbitrarily defined, and, like the divisions in systematic natural history, can only serve to bring the subject of our study better before us and to render it more manageable; but not to mark real distinctions between different things."—BERNHARD COTTA (1866).

OUR comparative study of the Anatomy and Ontogeny of the Amphioxus and the Ascidian has afforded us aid, the value of which can hardly be over-estimated, towards acquiring a knowledge of human Ontogeny. For in the first place we have in this way filled up, as regards Anatomy, the wide chasm which in all previous systems of the animal kingdom existed between Vertebrates and Invertebrates; and in the second place, in the germ-history of the Amphioxus we have recognized primordial phases of development, which have long disappeared from the Ontogeny of Man, and which have been lost in accordance with the law of abridged heredity. Of special importance among these phases of development is the Archigastrula, the original, genuine Gastrula-form which the Amphioxus has retained up to the present time, and which re-appears in the same form in low invertebrate animals of the most diverse classes.

The germ-history of the Amphioxus and the Ascidian has, therefore, so far perfected our direct knowledge of human genealogy, that, notwithstanding the incompleteness of our empiric knowledge, there is no essential gap of any great moment in the pedigree. We may, therefore, at once proceed to our task, and, aided by the ontogenetic and comparative-anatomical materials at our command, may reconstruct the main outlines of human Phylogeny. The immense importance of the direct application of the fundamental biogenetic law of the causal connection between Ontogeny and Phylogeny now becomes evident. But, before beginning this task, it will be well to note a few other general facts which may enable us better to understand the phenomena we are about to study.

Firstly, it may not be out of place to insert a few remarks as to the duration of time during which Man was developing from the animal kingdom. The first thought that occurs to the mind when we consider the facts in question, is of the immense difference between the duration of the germ-history of Man on the one hand, and of his tribal history on the other. The brief period in which the Ontogeny of the human individual takes place, bears no proportion to the infinitely long period required for the Phylogeny of the human tribe. The human individual requires nine months for its perfect development from the fertilized egg-cell to the moment at which it is born and quits the mother's body. The human embryo, therefore, passes through the whole course of its development in the brief space of 40 weeks (usually in exactly 280 days). Each man is really older by this period than is usually assumed. When, for example, a child is said to be 9¼ years old, he is in reality 10 years old. For individual existence does not begin at the moment of birth, but at the moment of fertilization. In many other Mammals the duration of the embryonic development is the same as in Man, *e.g.*, the Ox. In the Horse and the Ass it is somewhat longer, viz., from 43 to 45 weeks; in the Camel it is 13 months. In the largest Mammals the embryo requires a much longer time for its complete formation within the maternal body; in the Rhinoceros, for instance, 1½ year, in the Elephant 90 weeks. In the latter case, therefore, gestation lasts more than twice as long as in Man—for nearly a year and three quarters. In the smaller Mammals, the duration of embryonic development is, on the contrary, much shorter. The smallest Mammals, the Harvest Mice, develop fully in 3 weeks; Rabbits and Hares in 4 weeks; Rats and Marmots in 5 weeks; the Dog in 9, the Pig in 17, the Sheep in 21, and the Stag in 36 weeks. Development is yet more rapid in Birds. The Chick, under normal conditions of incubation, requires only 3 weeks, or just 21 days for its full development. The Duck, on the other hand, takes 25, the Turkey 27, the Peacock 31, the Swan 42, and the New Holland Cassowary 65 days. The smallest of all Birds, the Humming-bird, quits the egg after the twelfth day. It is, therefore, evident that in Mammals and in Birds the duration of development within the egg-membranes stands in a definite relation to the size of body attained by each vertebrate species. But the latter is not the sole determining cause of the former. There are many other circumstances which influence the duration of individual development within the membranes of the egg.[126]

In all cases, however, the duration of the Ontogeny appears infinitely brief when compared with the enormous, the infinitely long period during which the Phylogeny, or gradual development of the ancestral series, took place. This period is not to be measured by years and centuries, but by thousands and millions of years. Many millions of years must indeed have elapsed while the most perfect vertebrate organism, Man, gradually developed from the primæval one-celled ancestral organism. The opponents of the development theory, who regard this gradual development of Man from lower animal forms, and his original descent from a one-celled primitive animal as incredible, do not reflect that the very same marvel actually recurs before our eyes in the short space of nine months during the embryonic development of each human individual The same series of multifariously diverse forms, through which our brute ancestors passed in the course of many millions of years, has been traversed by every Man during the first 40 weeks of his individual existence within the maternal body.

All changes in organic forms, all metamorphoses of animal and plant forms, appear to us all the more remarkable and all the more wonderful in proportion as they occur more rapidly. When, therefore, our opponents pronounce that the past development of the human race from lower animal forms is incredible, they must regard the embryonic development of the human individual from the simple egg-cell as far more wonderful in comparison. This latter process—the ontogenetic modification—which takes place before our eyes, must appear more wonderful than the phylogenetic modification, in proportion as the duration of the tribal history exceeds that of the germ-history. For the human embryo must pass through the whole process of individual development, from the simple cell up to the many-celled perfect Man, with all his organs, in the brief space of 40 weeks. On the other hand, we may assign many millions of years for the accomplishment of the analogous process of phylogenetic development—the development of Man's ancestors from the simplest one-celled form.

As regards these phylogenetic periods, it is impossible to fix approximately their length in hundreds or in thousands of years, or to establish any absolute measure of their duration. But the researches of geologists have long since enabled us to estimate and compare the relative durations of the various periods of the earth's organic history. The most direct standard for determining the relative duration of geological periods is afforded by the thickness of the so-called Neptunian strata or sedimentary rock, *i.e.*, all those strata which have been deposited, as mud, at the bottom of the ocean, or under fresh water. These stratified sedimentary rocks—limestone, clay, marl, sandstone, slate, etc.—which constitute the great mass of mountain-chains, and which are often several thousand feet in thickness, afford us data for estimating the relative lengths of the various periods of the earth's history.

For the sake of completeness, I must say a few words as to the development of the earth as a whole, briefly indicating a few of the more prominent facts relating to this matter. At the very outset we are confronted with the weighty fact, that life originated on our planet at a certain definite period. This is a proposition that is no longer gainsaid by any competent geologist. We now know for certain that organic life upon our planet actually began at a certain time, and that it did not exist there from eternity, as some have supposed. The indisputable proofs of this are furnished, on the one hand, by physico-astronomical cosmogeny; on the other, by the Ontogeny of organisms. Species and tribes, like individuals, do not enjoy a perpetual life.[127] They also had a beginning. The time which has elapsed since the origin of life upon the earth up to the present time (and with this period of time alone we are here concerned) we call the "history of the organic earth," as distinguished from the "history of the inorganic earth" which embraces the period before the origin of organic life

With regard to the latter, we first obtained clear ideas from the natural philosophical researches and computations of the great critical philosopher, Immanuel Kant, and on this point I must refer the reader to Kant's "Allgemeine Naturgeschichte und Theorie des Himmels" and to the numerous Cosmogenies which treat the subject in a popular style. We cannot here dwell upon questions of this kind.

The organic history of the earth could begin only when water in fluid drops existed upon its surface. For the very existence of all organisms, without any exception, depends on water in the fluid state, their bodies containing a considerable amount of the same. Our own body, in its fully developed state, contains in its tissues 70 per cent. of water and only 30 per cent. of solid matter. The amount of water is still greater in the body of the child, and is greatest of all in the embryo. In early stages of development the human embryo contains more than 90 per cent. of water, and not 10 per cent. of solid matter. In low marine animals, especially in the Medusæ, the body contains even more than 99 per cent. of water, and not even one per cent. of solid matter. No organism can exist and perform its vital functions without water. Without water there is no life.

Water in the fluid state, which is, therefore, indispensable for the existence of life, could not, however, appear upon the earth until after the temperature of the surface of the fiery globe had sunk to a certain point. Before this it existed only in the form of steam. As soon, however, as the first drop of water in a fluid state was precipitated by cooling from the envelope of steam, it began its geological action, and from that time to this it has effected continual changes in the modification of the hard crust of the earth. The result of this unceasing work of the water, which in the form of rain and hail, of snow and ice, of rushing torrent and surging wave crumbles and dissolves the rocks, is the formation of ooze. As Huxley says, in his excellent "Lectures on the Causes of the Phenomena of Organic Nature," the most important fact in the past history of our earth is ooze, and the question as to the history of the past ages of the world resolves itself into a question as to the formation of ooze. All the stratified rocks of our mountainous formations were originally deposited as ooze at the bottom of the waters, and only afterwards hardened into solid stone.

As has already been said, it is possible, by bringing together and comparing the various rock-strata from many places on the surface of the earth, to obtain an approximate conception of the relative ages of these various strata. Geologists have long agreed that there is an entirely definite historical sequence of the various formations. The various groups of strata which lie one over another correspond to successive periods in the earth's organic history, during which they were deposited in the shape of mud at the bottom of the sea. Gradually this mud was hardened into solid rock. The latter, by alternate upheaval and depression of the surface of the earth, was lifted above the water, and assumed the form of mountains. Four or five main periods in the earth's organic history, answering to the larger and smaller groups of these sedimentary rock-strata, are usually distinguished. These main periods are subdivided into numerous subordinate or lesser periods. From twelve to fifteen of the latter are usually assumed. (Cf. Tables XII. and XIII., pp. 11, 12.) The relative thickness of the various groups of strata affords the means of approximately estimating the relative length of these various divisions of time. Of course we cannot say, "In a hundred years on the average a stratum of a certain thickness (say two inches) is deposited, and therefore a rock-stratum of a thousand feet in thickness is 600,000 years old." For different rock-formations of equal thickness may have occupied periods of very various length in their deposition and consolidation. From the thickness of the formation we may, however, approximately judge of the *relative* length of the period during which it was formed.

Of the four or five main periods of the earth's organic history, our acquaintance with which is indispensable for our Phylogeny of the human race, the first and oldest is known as the Primordial, Archizoic, or Archilithic Epoch. If we estimate the total thickness of all the sedimentary strata as averaging about 130,000 feet, then 70,000 feet belong to this first epoch—more than one half. From this and other circumstances we may conclude that the corresponding Primordial or Archilithic Epoch must alone have been considerably longer than the whole long period between the close of the Archilithic and the present time. Probably the Primordial Epoch was much longer than might appear from the ratio of 7 : 6, which we have given. This Epoch is divided into three sub-periods, known as the Laurentian, Cambrian, and Silurian, corresponding to the three principal groups of sedimentary rock-strata which constitute the Archilithic rocks. The enormous length of time required for the formation at the bottom of the primordial sea of these gigantic strata, of over 70,000 feet in thickness, must, at all events, have been many millions of years. During that time there came into existence by spontaneous generation the oldest and simplest organisms—those in which life began upon our planet—viz., the Monera. From these, one-celled plants and animals first developed—the Amœbæ and many kinds of Protista. During this same Archilithic Epoch, also, all the invertebrate ancestors of the human race developed from these one-celled organisms. We draw this conclusion from the fact that towards the close of the Silurian period a few remains of fossil Fishes are already to be found, viz., Selachians and Ganoids. These are, however, much more highly organized and of later origin than the lowest Vertebrates (the Amphioxus), or than the various skull-less Vertebrates allied to Amphioxus, which must have lived during this time. The latter must necessarily have been preceded by all the invertebrate ancestors of man. Hence we may characterize this entire epoch as the "age of man's invertebrate ancestors;" or, with special reference to the oldest representatives of the Vertebrate tribe, as the "age of Skull-less Animals." During the whole Archilithic Epoch the inhabitants of our planet consisted exclusively of aquatic forms; at least, no remains of terrestrial animals or plants dating from this period have as yet been found. A few remains of land-dwelling organisms which are sometimes referred to the Silurian Period, are Devonian.

The Primordial Epoch was followed by the Palæolithic, Palæozoic, or Primary Epoch, which is also separable into three sub-periods: the Devonian, the Carboniferous, and the Permian. During the Devonian Period the Old Red Sandstone, or Devonian system was formed; during the Carboniferous, those great beds of coal were deposited which

TABLE XII.

Systematic Survey of the Palæontological Periods, or the Greater Divisions in the History of the Organic Earth.

I. *First Epoch:* **The Archilithic,** *or Primordial Epoch.*

(Age of Skull-less Animals and Seaweed Forests.)

1. The Older Archilithic Epoch	or	Laurentian Period
2. The Middle Archilithic Epoch	"	Cambrian Period.
3. The Later Archilithic Epoch	"	Silurian Period.

II. *Second Epoch:* **The Palæolithic,** *or Primary Epoch.*

(Age of Fishes and Fern Forests.)

4. The Older Palæolithic Epoch	or	Devonian Period.
5. The Middle Palæolithic Epoch	"	Coal Period.
6. The Later Palæolithic Epoch	"	Permian Period.

III. *Third Epoch:* **The Mesolithic,** *or Secondary Epoch.*

(Age of Reptiles and Pine Forests, *Coniferæ*.)

7. The Older Mesolithic Epoch	or	Triassic Period.
8. The Middle Mesolithic Epoch	"	Jurassic Period.
9. The Later Mesolithic Epoch	"	Chalk Period.

IV. *Fourth Epoch:* **The Cænolithic,** *or Tertiary Epoch.*

(Age of Mammals and Leaf Forests.)

10. The Older Cænolithic Epoch	or	Eocene Period.
11. The Middle Cænolithic Epoch	"	Miocene Period.
12. The Later Cænolithic Epoch	"	Pliocene Period.

V. *Fifth Epoch:* **The Anthropolithic,** *or Quaternary Epoch.*

(Age of Man and Cultivated Forests.)

13. The Older Anthropolithic Epoch	or	Ice Age, Glacial Period.
14. The Middle Anthropolithic Epoch	"	Post Glacial Period.
15. The Later Anthropolithic Epoch	"	Period of Culture.

(**The Period of Culture** is the Historic Period, or **Period of Tradition.**)

TABLE XIII.

Systematic Survey of the Palæontological Formations, or the Fossiliferous Strata of the Earth's Crust.

Rock-Groups.	*Systems.*	*Formations.*	*Synonyms of Formations.*
V. *Quaternary Group*, or Anthropolithic (Anthropozoic) groups of strata	XIV. Recent (Alluvium)	36. **Present**	Upper alluvial
		35. **Recent**	Lower alluvial
	XIII. Pleistocene (Diluvium)	34. **Post glacial**	Upper diluvial
		33. **Glacial**	Lower diluvial
IV. *Tertiary Group*, or Cænolithic (Cænozoic) groups of strata	XII. Pliocene (New tertiary)	32. **Arvernian**	Upper pliocene
		31. **Sub-Appenine**	Lower pliocene
	XI. Miocene (Middle tertiary)	30. **Falunian**	Upper miocene
		29. **Limburgian**	Lower miocene
	X. Eocene (Old tertiary)	28. **Gypsum**	Upper eocene
		27. **Nummulitic**	Middle eocene
		26. **London clay**	Lower eocene
III. *Secondary Group*, or Mesolithic (Mesozoic) groups of strata	IX. Cretaceous.	25. **White chalk**	Upper cretaceous
		24. **Green sand**	Middle cretaceous
		23. **Neocomian**	Lower cretaceous
		22. **Wealden**	The Kentish Weald
	VIII. Jura	21. **Portlandian**	Upper oolite
		20. **Oxfordian**	Middle oolite
		19. **Bath**	Lower oolite
		18. **Lias**	Lias formation
	VII. Trias	17. **Keuper**	Upper trias
		16. **Muschelkalk**	Middle trias
		15. **Bunter sand**	Lower trias
II. *Primary Group*, or Palæolithic (Palæozoic) groups of strata	VI. Permian (New red sandstone)	14. **Mountain limestone** (*Zechstein*)	Upper Permian
		13. **Red sandstone**	Lower Permian
	V. Carboniferous (Coal)	12. **Carboniferous sandstone**	Upper carboniferous
		11. **Carboniferous limestone**	Lower carboniferous
	IV. Devonian (Old red sandstone)	10. **Pilton**	Upper Devonian
		9. **Ilfracombe**	Middle Devonian
		8. **Linton**	Lower Devonian
I. *Primordial Group*, or Archilithic (Archizoic) groups of strata	III. Silurian	7. **Ludlow**	Upper Silurian
		6. **Wenlock**	Middle Silurian
		5. **Llandeilo**	Lower Silurian
	II. Cambrian	4. **Potsdam**	Upper Cambrian
		3. **Longmynd**	Lower Cambrian
	I. Laurentian	2. **Labrador**	Upper Laurentian
		1. **Ottawa**	Lower Laurentian

supply us with our principal fuel; in the Permian, the New Red Sandstone, the Magnesian Limestone (Zechstein), and the Cupriferous Slate were formed. The approximate thickness of this entire group of strata is estimated at 42,000 feet at most; some geologists make it somewhat more, others considerably less. In any case, this Palæolithic Epoch, taken as a whole, is considerably shorter than the Archilithic, but yet is considerably longer than all the following Epochs taken together. The strata deposited during this Primary Epoch supply fossil animal remains in great abundance; besides numerous species of Invertebrates we find also very many Vertebrates—Fishes preponderating. As early as the Devonian, and even during the Carboniferous and the Permian Periods, there existed so great a number of Fishes, especially Primitive Fishes (Sharks) and Ganoids, that we may designate the entire Palæolithic Period as the *Age of Fishes.* The Palæozoic Ganoids especially are represented by a large number of forms.

But even during this period some Fishes began to accustom themselves to living upon the land, and thus gave rise to the Amphibian class. Even in the carboniferous system we find fossil remains of Amphibia—the earliest terrestrial and air-breathing animals. In the Permian Period the variety of these Amphibia becomes greater. Towards its close the first Amnion-animals, the tribal ancestors of the true higher Vertebrate classes, seem first to appear. These are a few lizard-like animals, of which the Proterosaurus from the Cupriferous Slate at Eisenach is the best known. The appearance of the most ancient Amnion Animals (*Amniota*), to which the common parent-form of

Reptiles, Birds, and Mammals must have belonged, seems in fact to be referred by these oldest reptilian remains back to the close of the Palæolithic Epoch. During this Epoch the ancestors of the human race must accordingly have been represented, first by true Fishes, then by Mud-Fishes (*Dipneusta*) and Amphibia, and finally by the oldest Amnion Animals, the Protamnia.

After the Palæolithic Epoch comes a third main division of the earth's organic history, known as the Mesolithic, or Secondary Epoch. This is again distinguished into three subdivisions—the Triassic, the Jurassic, and the Cretaceous Periods. The approximate thickness of the strata-groups, formed during these three Periods from the beginning of the Triassic down to the end of the Cretaceous Period, amounts in all to about 15,000 feet, not one half the thickness of the Palæolithic deposits. During this Epoch a very great and varied development took place in all divisions of the animal kingdom. In the vertebrate tribe especially a number of new and interesting forms developed. Among Fishes the Osseous Fishes (*Teleostei*) now first appear. But the Reptiles surpass all others both in numbers and in diversity of species—the most remarkable and the most familiar forms being the gigantic extinct Dragons (Dinosaurians), the Sea-Dragons (Halisaurians), and the Flying Lizards (Pterosaurians). In reference to this predominance of the reptilian class this time is known as the *age of reptiles.* But the class of Birds also developed during this period, undoubtedly originated from a branch of the lizard-like Reptiles. This is shown by the similar embryology of Birds and of Reptiles, by their Comparative Anatomy, and also by the fact that we know of fossil birds with toothed jaws and with lizard's tail, belonging to this period (*Odontornis Archæopteryx*). Finally, it was during this period that there appeared upon the scene that most perfect and, for us, most important vertebrate class, the mammalian class. The oldest fossil remains of these have been found in the most recent Triassic strata, viz., molar teeth of a small insectivorous Pouched Animal (Marsupial). Numerous remains occur somewhat later in the Jura system, and a few in the chalk. All the remains of Mammals from this Mesolithic Epoch with which we are acquainted belong to the low Pouched Animal division; and among these were undoubtedly the ancestors of Man. On the other hand, not a single undisputed relic has yet been discovered throughout all this period of one of the higher Mammals (*Placentalia*). This last division, of which Man is a member, did not develop till later, in the immediately subsequent Tertiary Epoch.

The fourth main division of the history of the organic earth, the Tertiary, Cænozoic, or Cænolithic Epoch, was of much shorter duration than the preceding. For the strata deposited during this period are in all only about 3000 feet in thickness. This Epoch, also, is divided into three subdivisions, known as the Eocene, Miocene, and Pliocene Periods. During these periods the most diverse development of the higher classes of plants and animals took place and the fauna and flora of our globe now approached nearer and nearer to their present character. The most highly developed class of animals, that of Mammals, now attained pre-eminence. This Tertiary Epoch may, therefore, be called the *age of Mammals*. The most perfect section of this class, the Placental Animals, among which is Man, now first appeared. The first appearance of Man—or to speak more correctly—the development of man from the most nearly allied ape-form, dates probably either from the Miocene or the Pliocene Period,—from the middle or the latest section of the Tertiary Epoch. Perhaps, as is assumed by others, Man strictly so-called, *i.e.*, Man gifted with language, first developed from the speechless man-like Apes, in the subsequent Anthropolithic Age.

At all events, the perfect development and distribution of the various races of Man dates from the fifth and last main division of the organic history of the earth, and hence this Epoch has been called the Anthropolithic, or Anthropozoic, and also the Quaternary Epoch. It is true that, in the present imperfect state of our palæontological and prehistoric knowledge, we cannot solve the problem as to whether the development of Man from the nearest allied Ape-forms took place in the beginning of this Anthropolithic Epoch, or as early as the middle or towards the close of the preceding Tertiary Epoch. This much, however, is certain, that the true development of human culture dates only from the Anthropolithic Epoch, and that this latter constitutes only an insignificantly small section of the entire enormous period of time occupied in the development of the organic earth. When we reflect upon this, it appears absurd to speak of the brief span of man's period of culture as "the world's history." This so-called History of the World does not amount approximately to even one-half per cent. of the length of those enormous periods which have passed away from the beginning of the earth's organic history down to the present time. For this World's

History, or more correctly, History of People, is itself only the latter half of the Anthropolithic Epoch, while even the first half of this Epoch must be reckoned as a prehistoric period. Hence this last main period, reaching from the close of the Cænolithic Epoch to the present time, can only be called the "age of man," inasmuch as the diffusion and differentiation of the different species and races of man, which have so powerfully influenced all the rest of the organic population of the globe, took place during its course.

Since the awakening of the human consciousness, human vanity and human arrogance have delighted in regarding Man as the real main-purpose and end of all earthly life, and as the centre of terrestrial Nature, for whose use and service all the activities of the rest of creation were from the first defined or predestined by a "wise providence." How utterly baseless these presumptuous anthropocentric conceptions are, nothing could evince more strikingly than a comparison of the duration of the Anthropozoic or Quaternary Epoch with that of the preceding Epochs. For even though the Anthropolithic Epoch may embrace several hundreds of thousands of years, how small is this time when compared with the millions of years that have elapsed since the beginning of the world's organic history down to the first appearance of the human race!

If the entire duration of the organic history of the earth, from the generation of the first Monera down to the present day, is divided into a hundred equal parts, and if then, corresponding with the relative average thickness of the intervening strata-systems, the respective percentages are assigned to the relative durations of the five main divisions or Epochs, the latter will be found to be about as follows:—

I.	Archilithic, or archizoic (primordial) Epoch . .	53.6
II.	Palæolithic, or palæozoic (primary) Epoch . .	32.1
III.	Mesolithic, or mesozoic (secondary) Epoch . .	11.5
IV.	Cænolithic, or cenozoic (tertiary) Epoch . . .	2.3
V.	Anthropolithic, or anthropozoic (quaternary) Epoch .	0.5
	Total ...	100.0

The relative durations of the five main epochs of the earth's organic history, are yet more clearly seen in the opposite Table (XIV.), in which the relative thicknesses of the strata systems deposited within these Epochs is represented on a scale corresponding to their actual depths.

This table shows that the period of the so-called History of the World forms but an inconsiderable span in comparison with the immeasurable duration of those earlier epochs during which Man did not exist upon this planet. Even the great Cænozoic Epoch, the so-called Tertiary Epoch, during which the Placental Animals, the higher Mammals, developed, includes but little more than two per cent. of the whole enormous duration of the organic history of the world.[128]

And now before we turn to our proper phylogenetic task; before, guided by our knowledge of ontogenetic facts and by the fundamental law of Biogeny, we attempt to trace step by step the history of the palæontological evolution of our animal ancestors, let us turn aside for a short time into another and apparently very different and very remote department of science, a general review of which will make the solution of the difficult problems which now rise before us very much easier. The science is that

TABLE XIV.

tematic Survey of the Neptunian fossiliferous strata of the earth with reference to their relative sectional thickness (130,000 feet circa).

IV. Cænolithic Strata, circa 3000 feet.	Pliocene, Miocene, Eocene.
III. Mesolithic Strata. Deposits of the Secondary Epoch, circa 15,000 feet.	IX. Chalk System.
	VIII. Jurassic System.
	VII. Triassic System
II. Palæolithic Strata. Deposits of the Primary Epoch, circa 42,000 feet.	VI. Permian System.
	V. Coal System.
	IV. Devonian System.
I. Archilithic Strata. Deposits of the Primordial Epoch, circa 70,000 feet.	III. Silurian System, circa 22,000 feet.
	II. Cambrian System, circa 18,000 feet.
	I. Laurentian System, circa 30,000 feet.

of Comparative Philology. Ever since Darwin, by the theory of Natural Selection, infused new life into Biology, and raised the fundamental question of development in every branch of science, attention has frequently and from very different quarters been called to the remarkable parallelism, which exists between the evolution of the various human languages and the evolution of organic species. The comparison is quite justifiable and very instructive. Indeed it is hardly possible to find an analogy better adapted to throw a clear light on many obscure and difficult facts in the evolution of species, which is governed and directed by the same natural laws which guide the course of the evolution of language.

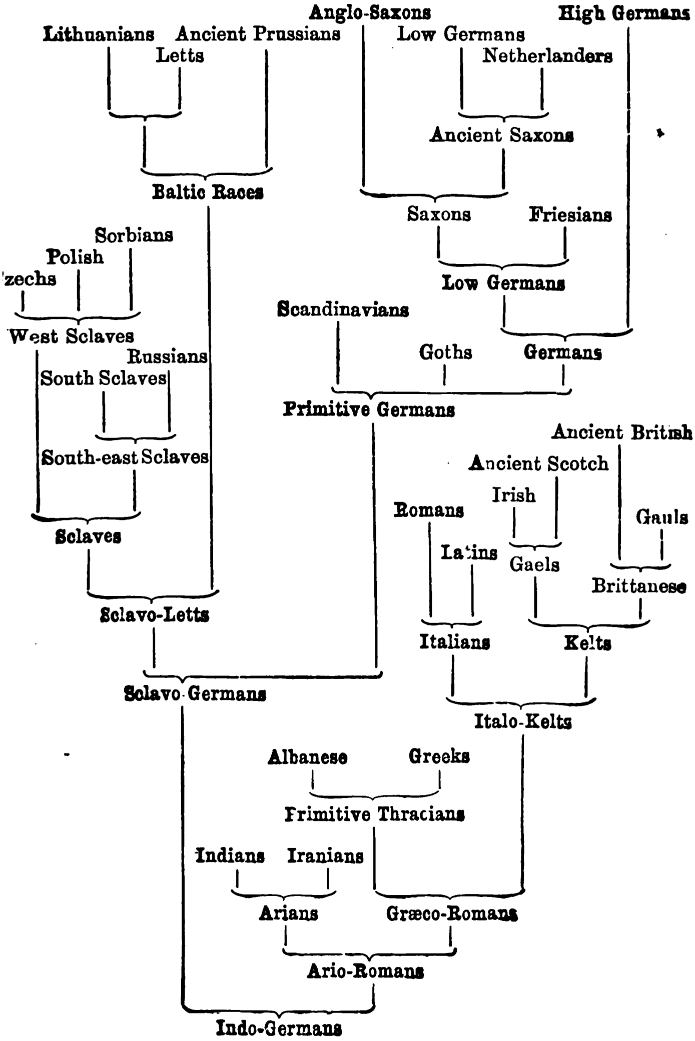
All philologists who have made any progress in their science, now unanimously agree that all human languages have developed slowly and by degrees from the simplest rudiments. On the other hand, the strange proposition which till thirty years ago was defended by eminent authorities, that language is a divine gift, is now universally rejected, or at best defended only by theologians and by people who have no conception of natural evolution. Such brilliant results have been attained in Comparative Philology that only one who is wilfully blind can fail to recognize the natural evolution of language. The latter is necessarily evident to the student of nature. For speech is a physiological function of the human organism, developing simultaneously with its special organs, the larynx and the tongue, and simultaneously with the functions of the brain. It is, therefore, quite natural that in the history of the evolution of languages, and in their whole system, we should find the same correlations as in the history of the evolution of organic species and in their whole system. The various larger and smaller groups of speech-forms, which are distinguished in Comparative Philology as primitive languages, fundamental languages, parent languages, derived languages, dialects, patois, etc., correspond perfectly in their mode of development with the various larger and smaller groups of organisms classed in systems of Zoology and Botany as tribes, classes, orders, families, genera, species, and varieties of the animal and vegetable kingdoms. The relations between these various systematic groups, or categories, are in both cases identical; moreover, evolution follows the same course in one case as in the other. This instructive comparison was first elaborated by one of the most eminent of German philologists, one who, unfortunately, died prematurely—August Schleicher, not only a philologist but also a learned botanist. In his more important works, the Comparative Anatomy and evolutionary history of languages is treated by the same phylogenetic method which we employ in the Comparative Anatomy and evolutionary history of animal forms. He has especially applied this method to the Indo-Germanic family of languages; and in his little treatise on "The Darwinian Theory and the Science of Language" ("Die Darwin'sche Theorie und die Sprachwissenschaft"), he illustrated it by means of a synoptical pedigree of the Indo-Germanic family of languages.[129]

If the formation of the various branch languages which have developed from the common root of the primitive Indo-Germanic tongue is studied with the aid of this pedigree, a very clear idea of their Phylogeny will be acquired. At the same time it becomes evident how entirely analogous is the evolution of the greater and lesser groups of the Vertebrates, which have sprung from the one common root-form of the primitive Vertebrates. The primitive Indo-Germanic root-tongue first separated into two chief stems: the Slavo-Germanic and the Ario-Romanic main-trunks. The Slavo-Germanic then branched into a primitive German and a primitive Slavo-Lettic tongue. Similarly, the Ario-Romanic split up into a primitive Arian and a primitive Græco-Romanic language (p. 23). If we continue our examination of this pedigree of the four primitive Indo-Germanic languages, we find that the primitive Germanic tongue divided into three chief branches—a Scandinavian, a Gothic, and a Teutonic branch. From the Teutonic branch proceeded, on the one hand, High German, and, on the other hand, Low German, to which latter belong the various Friesian, Saxon, and Low German dialects. Similarly, the Slavo-Lettic tongue developed first into a Baltic and a Slavonic language. From the Baltic spring the Lettic, Lithuanian, and Old Prussian dialects. The Slavic, on the other hand, give rise, in the South-east, to the Russian and the South Slavic dialects, and, in the West, to the Polish and Czech dialects.

Turning now to the other main stem of the Indo-Germanic languages and its branches—the primitive Ario-Romanic—it is found to develop with the same luxuriance. The primitive Græco-Romanic language gave rise, on the one hand, to the Thracian language (Albanian Greek), and on the other, to the Italo-Keltic. From the latter in turn sprung two divergent branches—in the South, the Italian branch (Romanic and Latin), and in the North, the Keltic, from which arose all the different British (Old British, Old Scottish, and Irish) and Gallic tongues. The numerous Iranian and Indian dialects branched out in the same way from the primitive Arian language.

TABLE XV.

Pedigree of the Indo-Germanic Languages.



A close study of this pedigree of the Indo-Germanic languages is, in many respects, of great interest. Comparative Philology, to which we are indebted for our knowledge of this subject, thus shows itself to be a true science—a *natural science.* It, indeed, long ago anticipated in its own province the phylogenetic method with the aid of which we now attain the highest results in Zoology and and in Botany. And here I cannot refrain from remarking how much to the advantage of our general culture it would be if the study of languages (which is undoubtedly one of the most powerful means of culture) were *comparatively* prosecuted; and if our cut and dried Philology were replaced by a living, many-sided, *comparative* study of languages. The latter stands in the same relation to the former as the living history of organic evolution does to the lifeless classification of species. How much deeper would the interest taken in the study of language by the students in our schools be, and how much more vivid would be the results if even the first elements of Comparative Philology were taught instead of the distasteful composition of Latin exercises in Ciceronian style!

I have entered with this detail into the "Comparative Anatomy" and the history of the evolution of languages, because it is unsurpassed as a means of illustrating the Phylogeny of organic species. We find that in structure and in development these primitive languages, parent languages, derived languages, and dialects, correspond exactly like the classes, orders, genera, and species of the animal kingdom. The "natural system" is in both cases phylogenetic. Just as Comparative Anatomy, Ontogeny, and Palæontology afford certain proof that all Vertebrates, whether extinct or extant, are descended from a common ancestral form, so does the comparative study of the dead and living Indo-Germanic language absolutely convince us that all these languages have sprung from a common origin. This monophyletic view is unanimously adopted by all linguists of importance who have studied the question, and who are capable of passing a critical judgment upon it.[130]

The point, however, to which I would specially call your attention in this comparison between the various branches, on the one hand, of the Indo-Germanic language, and, on the other, of the vertebrate tribe, is that the direct descendants must never be confounded with the collateral lines, nor the extinct with the extant forms. This mistake is often made, and results in the formation of erroneous notions of which our opponents often take advantage in order to oppose the whole theory of descent. When, for instance, it is said that human beings are descended from Apes, the latter from Semi-apes, and the Semi-apes from Pouched Animals (*Marsupialia*), very many people think only of the familiar living species of these different mammalian orders, such as are to be found stuffed in our museums. Now, our opponents attribute this erroneous view to us, and, with more craft than judgment, declare the thing impossible; or else they ask us as a physiological experiment to transform a Kangaroo into a Semi-ape, this into a Gorilla, and the Gorilla into a Man. Their demand is as childish as the conception on which it is founded is erroneous; for all these extant forms have varied more or less from their common parent-form, and none of them are capable of producing the same divergent posterity which were really produced thousands of years ago by that parent-form.[131]

There is no doubt that Man is descended from an extinct mammalian form, which, if we could see it, we should certainly class with the Apes. It is equally certain that this primitive Ape in turn descended from an unknown Semi-ape, and the latter from an extinct Pouched Animal. But then it is beyond a doubt that it is only in respect of essential internal structure, and on account of their similarity in the distinctive anatomical characters of the order, that all these extinct ancestral forms can be spoken of as members of the yet extant mammalian orders. In external form, in generic and specific characters, they must have been more or less—perhaps even greatly—different from all living representatives of the orders to which they belonged. For it must be accepted as a quite universal and natural fact in phylogenetic evolution that the parent-forms themselves, with their specific characters, became extinct at a more or less distant period. Those extant forms which come nearest to them, yet differ from them more or less, perhaps even very essentially. Hence in our phylogenetic researches and in our comparative view of the still living divergent descendants all we can undertake to do is to determine how far the latter depart from the parent-form. We may quite confidently assume that no single older parent-form has reproduced itself without modification down to our time.

We find this same state of things on comparing various extinct and living languages, which have sprung from one common primitive tongue. If, from this point of view, we examine the genealogical tree of the Indo-Germanic languages, we may conclude, on *à priori* grounds, that all the earlier primitive languages, fundamental languages, and ancestral languages, from which the living dialects are descended in the first or second degree, have been extinct for a longer or shorter period. And this is the case. The Ario-Romanic and the Sclavo-Germanic tongues have long been altogether extinct, as are also the primitive Arian and Græco-Romanic, the Sclavo-Lettic, and primitive Germanic languages. Some even of the languages descended from these have also long been dead, and all those of the Indo-Germanic branch which are yet extant, are akin only in so far as they are divergent descendants of common parent-forms. Some have diverged from this ancestral form more, others less.

This easily demonstrable fact very well illustrates analogous facts in the descent of vertebrate species. Phylogenetic "Comparative Philology," as a powerful ally, supports phylogenetic "Comparative Zoology." The former can, however, adduce far more direct evidence than the latter, because the palæontological materials of Philology, the ancient monuments of extinct tongues, have been far better preserved than the palæontological materials of Comparative Zoology, the fossil bones of vertebrates. The more these analogous conditions are considered, the more convincing is their force.

We shall presently find that we can trace back the genealogical line of Man, not only to the lower Mammals, but even to the Amphibia, to the shark-like Primitive Fishes, and even far below these, to the skull-less Vertebrates allied to the Amphioxus. It must be remembered this does not mean that the living Amphioxus, Shark, or Amphibian accurately represent the outward appearance of the parent-forms of which we speak. Still less does it mean that the Amphioxus, or the Shark of our day, or any extant species of Amphibian is an actual parent-form of the higher Vertebrates and of Man. On the contrary, this important assertion must be clearly understood to mean, that the living forms, which have been mentioned, are side branches, which are much more nearly allied, and similar to the extinct common parent-forms, than any other known animal forms. In their internal characteristic structure they remain so similar to the unknown parent-forms, that we should class them both in one order, if we had the latter before us in a living state. But the direct descendants of the primitive forms have never remained unmodified. Hence it is quite impossible that among the living species of animals we should find the actual ancestors of the human race in their characteristic specific forms. The essential and characteristic features, which more or less closely connect living forms with the extinct common parent-forms, are to be found in the internal structure of the body, not in the external specific form. The latter has been much modified by adaptation. The former has been more or less retained by heredity.

Comparative Anatomy and Ontogeny indisputably prove that Man is a true Vertebrate, so that the special genealogical line of Man must of course be connected with that of all those Vertebrates which are descended from the same common root. Moreover, on many definite grounds, supplied by Comparative Anatomy and Ontogeny, we must assume only one common origin for all Vertebrates—a monophyletic descent. Indeed, if the theory of descent is correct, all Vertebrates, Man included, can only have descended from a single common parent-form—from a single primitive Vertebrate species. The genealogical line of the Vertebrates, therefore, is also that of Man.

Our task of ascertaining a pedigree of Man thus widens into the more considerable task of constructing the pedigree of all the Vertebrates. This is connected, as we learned from the Comparative Anatomy and Ontogeny of the Amphioxus and of the Ascidian, with the pedigree of the Invertebrate animals, and directly with that of the Worms, while no connection can be shown with the genealogy of the independent tribes of the Articulated Animals (*Arthropoda*), Soft-bodied Animals (*Mollusca*), and Star-animals (*Echinoderma*). As the Ascidian belongs to the Mantled Animals (*Tunicata*), and as this class can only be referred to the great Worm tribe, we must, aided by Comparative Anatomy and Ontogeny, further trace our pedigree down through various stages to the lowest forms of Worms. This necessarily brings us to the Gastræa, that most important animal form in which we recognize the simplest conceivable prototype of an animal with two germ-layers. The Gastræa itself must have originated from among those lowest of all simple animal forms, which are now included by the name of Primitive Animals (*Protozoa*). Among these we have already considered that primitive form which possesses most interest for us—the one-celled Amœba, the peculiar significance of which depends on its resemblance to the human egg-cell. Here we have reached the lowest of those impregnable points, at which the value of our fundamental law of Biogeny is directly found, and at which, from the embryonic evolutionary stage, we can directly infer the extinct parent-form. The amœboid nature of the young egg-cell, and the one-celled condition in which each Man begins his existence as a simple parent-cell or cytula-cell, justify us in affirming that the oldest ancestors of the human race (as of the whole animal kingdom) were simple amœboid cells.

Here arises another question: "Whence, in the beginning of the organic history of the earth, at the commencement of the Laurentian period, came the earliest Amœbæ?" To this there is but one reply. Like all one-celled organisms, the Amœbæ have originally developed only from the simplest organisms know to us, the Monera. These Monera, which we have already described, are also the simplest conceivable organisms. Their body has no definite form, and is but a particle of primitive slime (plasson)—a little mass of living albumen, performing all the essential functions of life, and everywhere met with as the material basis of life. This brings us to the last, or perhaps the first question in the history of evolution—the question as to the origin of the Monera. And this is the momentous question as to the prime origin of life—the question of spontaneous generation (*generatio spontanea* or *æquivoca*).

We have neither time, nor indeed have we any occasion, to discuss at length the weighty question of spontaneous generation. On this subject I must refer you to my "History of Creation," and, especially, to the second book of the *Generelle Morphologie*, and to the discussion on Monera and spontaneous generation in my "Studien über Moneren und andere Protista."[182] I have there stated my own views on this important subject in very great detail. Here I will only say a few words on the obscure question as to the first origin of life, and will answer it so far as it concerns our radical conception of the history of organic evolution. In the definite, limited sense in which I maintain spontaneous generation (*generatio spontanea*) and assume it as a necessary hypothesis in explanation of the first beginning of life upon the earth, it merely implies the origin of Monera from inorganic carbon compounds. When animated bodies first appeared on our planet, previously without life, there must, in the first place, have been formed, by a process purely chemical, from purely inorganic carbon combinations, that very complex nitrogenized carbon compound which we call plasson, or "primitive slime," and which is the oldest material substance in which all vital activities are embodied. In the lowest depths of the sea such homogeneous amorphous protoplasm probably still lives, in its simplest character, under the name of Bathybius.[137] Each individual living particle of this structureless mass is called a Moneron. The oldest Monera originated in the sea by spontaneous generation, just as crystals form in the matrix. This assumption is required by the demand of the human understanding for causality. For when, on the one hand, we reflect that the whole inorganic history of the earth proceeds in accordance with mechanical laws and without any intervention by creative power, and when, on the other hand, we consider that the entire organic history of the world is also determined by similar mechanical laws; when we see that no supernatural interference by a creative power is needed for the production of the various organisms, then it is certainly quite inconsistent to assume such supernatural creative interference for the first production of life upon our globe. At all events we, as investigators of nature, are bound at least to attempt a natural explanation.

At present, the much agitated question of spontaneous generation appears very intricate, because a large number of very different, and in part quite absurd, conceptions are included under the term "spontaneous generation," and because some have supposed that the problem could be solved by means of the crudest experiments. The doctrine of spontaneous generation cannot be experimentally refuted. For each experiment with a negative result merely proves that under the conditions (always very artificial) supplied by us, no organism has been produced from inorganic combinations. Neither can the theory of spontaneous generation be experimentally proved unless great difficulties are overcome; and even if in our own time Monera were produced daily by spontaneous generation—as is very possible—yet the absolute empiric proof of this fact would be extremely difficult—indeed, in most cases impossible. He, however, who does not assume a spontaneous generation of Monera, in the sense here indicated, to explain the first origin of life upon our earth, has no other resource but to believe in a supernatural miracle; and this, in fact, is the questionable standpoint still taken by many so-called "exact naturalists," who thus renounce their own reason.

Sir William Thomson has indeed tried to avoid the necessary hypothesis of spontaneous generation by assuming that the organic inhabitants of our earth originally descended from germs which proceeded from the inhabitants of other planets, and which, with fragments of the latter, with meteorites, accidentally fell on to the earth. This hypothesis has met with much applause, and was even supported by Helmholtz. Friederich Zoellner, an acute physicist, has, however, refuted it in his excellent natural-philosophical work "Ueber die Natur der Cometen," a critical book containing most valuable contributions to the history and theory of knowledge.[127] Zoellner has plainly shown that the hypothesis is unscientific in two respects—

firstly, in point of logic, and secondly, in its scientific tenor (p. xxvi). At the same time he rightly shows that the hypothesis of spontaneous generation, in the sense which we have defined, is the "condition necessary to the conceivability of nature in accordance with the laws of causality."

In conclusion, I repeat, with emphasis, that it is only in the case of Monera—of structureless organisms without organs—that we can assume the hypothesis of spontaneous generation. Every differentiated organism, every organism composed of organs, can only have originated from an undifferentiated lower organism by differentiation of its parts, and consequently by Phylogeny. Hence, even in the production of the simplest cell we must not assume the process of spontaneous generation. For even the simplest cell consists of at least two distinct constituent parts; the inner and firmer kernel (nucleus), and the outer and softer cell-substance or protoplasm. These two distinct parts can only have come into being by differentiation of the homogeneous plasson of a moneron and of a cytod. It is for this very reason that the natural history of Monera is of the highest interest; for it alone can remove the principal difficulties which beset the question of spontaneous generation. The extant Monera do afford us organless and structureless organisms, such as must have originated by spontaneous generation at the first beginning of organic life upon the earth.[133]

CHAPTER XVI.

THE ANCESTRY OF MAN.

I. FROM THE MONERA TO THE GASTRÆA.

Relation of the General Inductive Law of the Theory of Descent to the Special Deductive Laws of the Hypotheses of Descent.—Incompleteness of the Three Great Records of Creation: Palæontology, Ontogeny, and Comparative Anatomy.—Unequal Certainty of the Various Special Hypotheses of Descent.—The Ancestral Line of Men in Twenty-two Stages: Eight Invertebrate and Fourteen Vertebrate Ancestors.—Distribution of these Twenty-two Parent-forms in the Five Main Divisions of the Organic History of the Earth.—First Ancestral Stage: Monera.—The Structureless and Homogeneous Plasson of the Monera.—Differentiation of the Plasson into Nucleus, and the Protoplasm of the Cells.—Cytods and Cells as Two Different Plastid-forms.—Vital Phenomena of Monera.—Organisms without Organs.—Second Ancestral Stage: Amœbæ.—One-celled Primitive Animals of the Simplest and most Undifferentiated Nature.—The Amœboid Egg-cells.—The Egg is Older than the Hen.—Third Ancestral Stage: Syn-Amœba, Ontogenetically reproduced in the Morula.—A Community of Homogeneous Amœboid Cells.—Fourth Ancestral Stage: Planæa, Ontogenetically reproduced in the Blastula or Planula.—Fifth Ancestral Stage: Gastræa, Ontogenetically reproduced in the Gastrula and the Two-layered Germ-disc.—Origin of the Gastræa by Inversion (*invaginatio*) of the Planæa.—Haliphysema and Gastrophysema.—Extant Gastræads.

"Now, very probably, if the course of evolution proves to be so very simple, it will be thought that the whole matter is self-evident, and that research is hardly required to establish it. But the story of Columbus and the egg is daily repeated; and it is necessary to perform the experiment for one's self. How slowly progress is made in the knowledge even of self-evident matters, especially when respectable authorities disagree, I myself have experienced sufficiently."—KARL ERNST BAER (1828).

GUIDED by the fundamental law of Biogeny and by the sure records of creation, we now turn to the interesting task of examining the animal parent-forms of the human race in their proper sequence. To ensure accuracy, we must first become acquainted with the various mental operations which we shall apply in this natural-philosophical research. These operations are partly of an inductive, partly of a deductive nature; partly conclusions from numerous particular experiences to a general law; partly conclusions from this general law back to particular experiences.

Tribal history as a whole is an inductive science; for the whole theory of descent, as an indispensable and most essential part of the whole theory of evolution, is entirely founded on inductions. From all the biological incidents in plant life, in animal life, and in human life, we have derived the certain inductive conception that the whole of the organic inhabitants of our globe originated in accordance with one single law of evolution. To this law of evolution, Lamarck, Darwin, and their successors gave definite form in the theory of descent. All the interesting phenomena exhibited by Ontogeny, Palæontology, Comparative Anatomy, Dysteleology, Chorology, the Œkology of organisms, all the important general laws, which we infer from multitudinous phenomena of these different sciences, and which are most intimately connected together, are the broad inductive data from which is drawn the most extensive inductive law of Biology. Because the innate connection between all these infinitely various groups of phenomena in these different departments becomes explicable and comprehensible solely through the theory of descent, therefore this theory of evolution must be regarded as an extensive inductive law. If we now really apply this inductive law, and with its help seek to discover the descent of individual organic species, we must necessarily form phylogenetic hypotheses, which are of an essentially deductive nature, and which are inferences from the general theory of descent back to individual particular cases. These special deductive conclusions are, however, in accordance with the inexorable laws of Logic, as justifiable, as necessary, and as indispensable in our department of knowledge as the general inductive conclusions of which the whole theory of evolution is formed. The doctrine of the animal parent-forms of mankind is also a special deductive law of this kind, which is the logical conclusion from the general inductive law of the theory of descent.[134]

As is now very generally acknowledged, both by the adherents of and the opponents of the theory of descent, the choice, in the matter of the origin of the human race, lies between two radically different assumptions: We must either accustom ourselves to the idea that all the various species of animals and plants, Man also included, originated independently of each other by the supernatural process of a divine "creation," which as such is entirely removed from the sphere of scientific observation—or we are compelled to accept the theory of descent in its entirety, and trace the human race, equally with the various animal and plant species, from an entirely simple primæval parent-form. Between these two assumptions there is no third course. Either a blind belief in creation, or a scientific theory of evolution. By assuming the latter, and this is the only possible natural-scientific conception of the universe, we are enabled, with the help of Comparative Anatomy and Ontogeny, to recognize the human ancestral line with a certain approximate degree of certainty, just as is more or less the case with respect to all other organisms. Our previous study of the Comparative Anatomy and Ontogeny of Man, and of other Vertebrates, has made it quite clear that we must first seek the pedigree of mankind in that of the vertebrate tribe. There can be no doubt that (if the theory of descent is correct) Man has developed as a true Vertebrate, and that he originated from one and the same common parent-form with all other Vertebrates. This special deduction must be regarded as quite certain, correctness of the inductive law of the theory of descent being of course first granted. No single adherent of the latter can raise a doubt about this important deductive conclusion. We can, moreover, name a series of different forms of the vertebrate tribe, which may be safely regarded as the representatives of different successive phylogenetic stages of evolution, or as different members of the human ancestral line. We can also prove with equal certainty that the vertebrate tribe as a whole originated from a group of low invertebrate animal forms; and among these we can again with more or less certainty recognize a series of members of the ancestral chain.

We must, however, at once expressly say that the certainty of the different hypotheses of descent, which are founded entirely on special deductive inferences, is very unequal. Several of these conclusions are already fully established; others, on the contrary, are most doubtful; in yet others, it depends upon the subjective proportion of the knowledge of the naturalist and on his capability of drawing conclusions, what degree of probability he will accord to them. It is, at all events, necessary thoroughly to distinguish between the *absolute* certainty of the general (inductive) theory of descent, and the *relative* certainty of the special (deductive) hypothesis of descent. We can never in any case prove the whole ancestral line of ancestors of an organism with the same certainty with which we regard the theory of descent as the only scientific explanation of the organic forms. On the contrary, the special proof of all separate parent-forms must always remain more or less incomplete and hypothetical. That is quite natural. For all the records of creation upon which we rely are in a great measure incomplete, and will always remain incomplete; just as in the case of Comparative Philology.

Above all, Palæontology, the most ancient of all records of creation, is in the highest degree incomplete. We know that all the petrifications with which we are acquainted form but an insignificantly small fragment of the whole number of animal forms and plant forms which have ever existed. For each extinct species obtained by us in a petrified condition, there are at least a hundred, probably thousands of extinct species which have left no trace of their existence. This extreme and most deplorable defectiveness of the palæontological record of creation, upon which it is impossible to insist too strongly, is very easily accounted for. The very conditions under which organic remains become petrified necessitate it. It is also partly explicable as the result of an imperfect knowledge in this department. It must be remembered, that far the greater proportion of the rock strata which constitute the mountain masses of the surface of the earth is not yet unfolded to us. Of the countless petrifications which are hidden in the huge mountain chains of Asia and Africa, we know but a few small samples. Part of Europe and of North America has alone been more minutely explored. The whole of the petrifactions accurately known and in our collections do not amount to a hundredth part of those which really exist in the crust of the earth. In this respect we may, therefore, expect a rich harvest of discoveries in the future. But, in spite of this, the palæontological record of creation (for reasons which I have amply explained in Chapter XV. of my "Natural History of Creation") will always remain extremely incomplete.

Not less incomplete is the second, most important record of creation, that of Ontogeny. For the Phylogeny of the individual it is the most important of all. Yet, it also has its great defects, and often leaves us in the lurch. In this matter, we must distinguish quite clearly between palingenetic and kenogenetic phenomena, between the original, inherited evolution and the later, vitiated evolution. We must never forget that the laws of abridged and vitiated heredity frequently disguise the original course of evolution beyond recognition. The reproduction of the Phylogeny in the Ontogeny is but rarely tolerably complete. The earliest and most important stages of germ-history are usually the most abridged and compressed. The youthful evolutionary forms have in turn often adapted themselves to new conditions, and have thus been modified. The struggle for existence has excited an equally strong modifying influence upon the various independent and yet undeveloped young forms, as upon the developed and mature forms. Therefore, in the Ontogeny of the higher animal forms, the Phylogeny has been very greatly limited by Kenogenesis; as a rule, only a blurred and much vitiated picture of the original course of evolution of their ancestors now lies before us in the Ontogeny. Only with great precaution and judgment dare we infer the tribal history directly from the germ-history. Moreover, the germ-history itself is known to us only in the case of very few species.

Lastly, the highly important record of creation afforded by Comparative Anatomy is unfortunately very incomplete, and for the simple reason, that the number of extant animal species forms but a very small fragment of the whole number of different animal forms that have existed from the beginning of the organic history of the world to the present time. The total sum of the latter may safely be estimated at several millions. The number of those animals the organization of which has at present been investigated by Comparative Anatomy is very small in proportion. The more extended investigations of the future will, here also, open up unexpected treasures.

In view of this evident and natural incompleteness of the most important records of creation, we must of course take good care, in the tribal history of Man, not to lay too great weight on single known animal forms, nor with equal certainty to consider all the stages of evolution which come under our consideration, as parent-forms. On the contrary, in hypothetically arranging our ancestral line, we must take good care to remember that the single hypothetical parent-forms are of very diverse values in relation to the certainty of our knowledge. From the few remarks which, while speaking of the Ontogeny, we made as to the corresponding phylogenetic forms, it will have been understood that some germ-forms may with certainty be regarded as reproductions of corresponding parent-forms. We recognized the human egg-cell and the parent-cell which results from the impregnation of the latter as the first and most important form of this kind.

From the weighty fact that the egg of the human being, like the egg of all other animals, is a simple cell, it may be quite certainly inferred that a one-celled parent-form once existed, from which all the many-celled animals, Man included, developed.

A second very significant germ-form, which evidently reproduces a primæval parent-form, is the germ-vesicle (*Blastula*), a simple hollow sphere, the wall of which consists of a single cell-stratum. A third extremely important form in germ-history, which may be quite safely and directly referred back to the tribal history, is the true Gastrula. This most interesting larval form already exhibits the animal body composed of two germ-layers, and furnished with the fundamental primitive organ, the intestinal canal. Now, as the same two-layered germ-condition, with the primitive rudiment of the intestinal canal, is common to all the other animal tribes (with the single exception of the Primitive Animals, *Protozoa*), we may certainly from this infer a common parent-form of similar construction to the Gastrula, the Gastræa. Equally important in their bearing on the Phylogeny of Man, are the very important ontogenetical form conditions which correspond to certain Worms, Skull-less Animals (*Acrania*), Fishes, etc., etc. On the other hand, between these quite certain and most valuable phylogenetic points, great gaps in our knowledge unfortunately exist, with which we shall again and again meet, and which are satisfactorily explained by reasons which have already been named, especially by the incompleteness of Palæontology, of Comparative Anatomy, and Ontogeny.

In the first attempts to construct the human ancestral line, which I made in my *Generelle Morphologie*, and in the "Natural History of Creation," I arranged first ten, and, later, twenty-two different animal forms, which, with more or less certainty, may be regarded as the animal ancestors of the human race, and which must be looked upon as in a sense the most important stages of evolution in the long evolutionary series from the one-celled organisms up to Man.[135] Of these twenty to twenty-two animal forms, about eight fall within the older division of the Invertebrates, while twelve to fourteen belong to the more recent Vertebrate division. How these twenty-two most important parent-forms in the human ancestral line are distributed through the five main periods of the organic history of the earth, is shown in the following Table (XVI.). At least half of these twenty-two stages of evolution (that is, the eleven oldest ancestral forms) are found within the Archilithic Epoch, within that first main period of the organic history of the earth, which includes the larger half of the latter, and during which probably only aquatic organisms existed. The eleven remaining parent-forms fall within the four remaining main Epochs: three within the Palæolithic Epoch, three within the Mesolithic Epoch, and four within the Cænolithic Epoch. In the last, the Anthropolithic Age, Man already existed.

If we would now undertake the difficult attempt to discover the phylogenetic course of evolution of these twenty-two human ancestral stages from the very commencement of life, and if we venture to lift the dark veil which covers the oldest secrets of the organic history of the earth, we must undoubtedly seek the first beginning of life among those wonderful living beings which, under the name of Monera, we have already frequently pointed out as the simplest known organisms. They are, at the same time, the simplest conceivable organisms; for their entire body, in its fully developed and freely moving condition, consists merely of a small piece of structureless primitive slime or plasson, of a small fragment of that extraordinarily important nitrogenous carbon compound, which is now universally esteemed the most important material substratum of all the active phenomena of life. The experiences of the last ten years particularly have convinced us with more and more certainty that wherever a natural body exhibits the active phenomena of life, nutrition, propagation, spontaneous movement, and sensation, a nitrogenous carbon compound, belonging to the chemical group of albuminous bodies, is always active, and represents the material substance through which these vital activities are effected. Whether, in a monistic sense, we conceive the function as the direct effect of the formed material substance, or, in a dualistic sense, we regard " Matter and Force " as distinct, it is at least certain that, hitherto, no living organism has been observed in which the exercise of vital activities was not inseparably connected with a plasson-body. In the Monera, the simplest conceivable organisms, the whole body consists merely of plasson, corresponding to the " primitive slime " of earlier natural philosophy.

TABLE XVI.

Systematic Survey of the most Important Stages in the Animal Ancestral Line of Man.

M N = Boundary between the Invertebrate and the Vertebrate Ancestors.

Epochs of the Organic History of the Earth.	*Geological Periods of the Organic History of the Earth.*	*Animal Ancestral Stages of Man.*	*Nearest Living Relatives of the Ancestral Stages.*
I. Archilithic or Primordial Epoch	1. Laurentian Period 2. Cambrian Period 3. Silurian Period	1. Monera (*Monera*)	Bathybius Protamœba
		2. Oldest Amœbæ	Simple Amœbæ (*Automœba*)
		3. Amœboid Societies (*Synamœbia*)	Morula larvæ
		4. Ciliated planulæ (*Planæadæ*)	Blastula larvæ
		5. Primitive Intestinal animals (*Gastræadæ*)	Gastrula larvæ
		6. Primitive Worms (*Archelminthes*)	Gliding Worms (*Turbellaria*)
		7. Soft-worms (*Scolecida*)	? Between the gliding worms and the Sea-squirts
		8. Chorda animals (*Chordonia*)	Sea-squirts (*Ascidiæ*) (*Appendiculariæ*)
		M..	....N
		9. Skull-less animals (*Acrania*)	Lancelets (*Amphioxi*)
		10. Round-mouths (*Cyclostomi*)	Lampreys (*Petromyzonta*)
		11. Primitive Fishes (*Selachii*)	Sharks (*Squalacei*)
II. Palæolithic or Primary Epoch	4. Devonian Period 5. Coal Period 6. Permian Period	12. Salamander Fishes (*Dipneusta*)	Mud fish (*Protoptera*)
		13. Gilled Amphibia (*Sozobranchia*)	Siren (*Proteus*) and Axolotl (*Siredon*)
		14. Tailed Amphibia (*Sozura*)	Water-newt (*Triton*)
III. Mesolithic or Secondary Epoch	7. Triassic Period 8. Jurassic Period 9. Chalk Period	15. Primitive Amniota (*Protamnia*)	? Between Tailed Amphibians and Beaked animals
		16. Primitive Mammals (*Promammalia*)	Beaked animals (*Monotrema*)
		17. Pouched Animals (*Marsupialia*)	Pouched Rats (*Didelphyes*)
IV. Cænolithic or Tertiary Epoch	10. Eocene Period 11. Miocene Period 12. Pliocene Period	18. Semi-Apes (*Prosimiæ*)	Lori (*Stenops*) Maki (*Lemur*)
		19. Tailed Narrow-nosed Apes	Nose Apes Holy Apes
		20. Men-like Apes or Tail-less Narrow-nosed Apes.	Gorilla, Chimpanzee, Orang, Gibbon
		21. Speechless Men or Ape-like Men	Cretins or Microcephali
V. Quaternary Epoch	13. Diluvial Period 14. Alluvial Period	22. Men capable of speech	Australians and Papuans

The soft slimelike plasson-substance of the body of th Moneron is commonly called "*protoplasma*," and identified with the cell-substance of ordinary animal and plant cells. As, however, Eduard van Beneden, in his excellent work upon the Gregarinæ, first clearly pointed out, we must, strictly speaking, distinguish thoroughly between the plasson of cytods and the protoplasm of cells. This distinction is of special importance in its bearing on the history of evolution. As was before incidentally mentioned, we must assume two different stages of evolution in those elementary organisms, which, as formative particles or plastids, represent organic individuality of the first order. The older and lower stage is that of the cytods, in which the whole body consists of but one kind of albuminous substance, of the simplest plasson or formative material. The more recent and higher stage is that of cells, in which a separation or differentiation of the original plasson into two different kinds of albuminous substances, into the inner cell-kernel (*nucleus*), and the outer cell-substance (*protoplasma*), has already taken place.

The Monera are the simplest permanent cytods. Their entire body consists merely of soft, structureless plasson. However thoroughly we examine them with the help of the most delicate chemical reagents and the strongest optical instruments, we yet find that all the parts are completely homogeneous. These Monera are, therefore, in the strictest sense of the word, "organisms without organs;" or even, in a strictly philosophical sense, they might not even be called "organisms," since they possess no organs, since they are not composed of various particles. They can only be called organisms, in so far as they are capable of exercising the ganic phenomena of life, of nutrition, reproduction, sensation, and movement. If we tried to construct, *à priori*, the simplest conceivable organism, we should always be compelled to fall back upon such a Monera.

Although in all real Monera the body consists merely of such a small living piece of plasson, yet, among the Monera, which have been observed in the sea and in fresh water, we have been able to distinguish several different genera and species, varying in the mode in which their tiny bodies move and reproduce. In the ways in which movement is accomplished very noticeable differences exist.

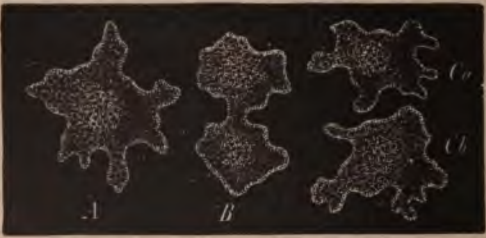


FIG. 163.—A Moneron (*Protamœba*) in the act of reproduction: *A*, the whole Moneron, which moves, like the ordinary Amœba, by means of variable processes; *B*, a contraction round its circumference parts it into two halves; *C*, the two halves separate, and each now forms an independent individual (much enlarged).

In some Monera, especially in the Protamœba (Fig. 163), the formless body, during its movements, invariably develops only a few, short, and blunt processes, which project like fingers, slowly altering their form and size, but never branching. In other Monera, on the other hand (*e.g.*, *Protomyxa*, *Myxastrum*), very numerous, long, fine, and generally thread-like processes arise from the surface of the movable body, and these branch irregularly, intertwining their free moving ends, so as to form a net. Huge masses of such slime-nets crawl upon the deepest bottom of the sea (*Bathybius*, Fig. 164). Within these soft slime-like plasson-nets slow currents continually pass. Such a Moneron may be fed with finely pulverized colouring matter (for instance, carmine or indigo powder), if this powder is scattered in the drop of water under the microscope, in which the Moneron is contained. The grains of colouring matter at first adhere to the surface of the slimy body, and then gradually penetrate, and are driven about in irregular directions. The separate smallest particles, or molecules, of the Moneron-body, called "plastidules,"[136] displace each other, change their relative positions, and thus effect a change in the position of the absorbed particles of colouring matter. This change of position, at the same time, proves positively that a hidden delicate structure does not exist. It might be argued that the Monera are not really structureless, but that their organization is so minute that, in consequence of the inadequate power of our magnifying glasses, it is invisible. This objection is, however, invalid, for by the experiment of feeding, we can, at any moment, prove the entrance of foreign, formed, small bodies into the different parts of the body of the Moneron, and that these are irregularly driven about in all directions. At the same time we see that the changeable network of threads, formed by the branching of the protoplasmic threads and the coalescence of the confluent branches, alter their configuration every moment; just as has long been known to occur in the thread-nets of the protoplasm in the interior of the plant-cells. The Monera are, therefore, really homogeneous and structureless;

each part of the body is every other part. Each part can absorb and digest nourishment; each part is excitable and sensitive; each part can move itself independently; and lastly, each part is capable of reproduction and regeneration.

The reproduction of Monera always occurs asexually. In the Protamœba (Fig. 163), each individual, after it has grown to a certain size, simply separates into two pieces. Round the circumference of the body a contraction arises, as in cell-division. The connection between the two halves continually becomes more slender (*B*), and finally parts in the middle. Thus, in the simplest possible way, two new individuals proceed by self-division from one quite simple individual (*C*). Other Monera, after they have grown to a certain size, gather themselves together into a spherical form. The globular protoplasmic body exudes a jelly-like protecting envelope, and a breaking-up of the whole plasson-ball takes place within this covering; it breaks either into four pieces (*Vampyrella*), or into a large number of smaller globules (*Protomonas, Protomyxa*; cf. Plate I. in the "Natural History of Creation"). After a time, these globules begin to move, split the integument by their movement, and emerge; after which they float about by means of a long, thin, thread-shaped process. Each again passes by simple growth into the mature form. Thus, it is possible to distinguish different genera and species of Monera, on one hand, by the form of the different processes of the body, and, on the other hand, by the different kind and manner of reproduction. In the appendix to my monograph of the Monera I enumerated eight genera and sixteen species ("Biol. Studien," vol. i. p. 182). The most remarkable of all Monera is the Bathybius, which was discovered by Huxley in 1868 (Fig. 164). This wonderful Moneron lives in the deepest parts of the sea, especially in the Atlantic Ocean, and in places covers the whole floor of the sea in such masses, that the fine mud on the latter consists, in great measure, of living slime. The protoplasm in these formless nets does not seem differentiated at all; each little piece is capable of forming an individual. The active amœboid movements of these formless pieces of plasson, which were first observed by the English zoologists Carpenter and Wyville Thomson, have recently been again observed by the German Arctic voyager, Emil Bessels, in the Bathybius of the coast of Greenland.[137]

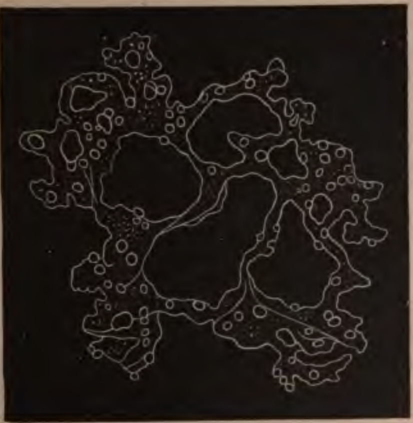
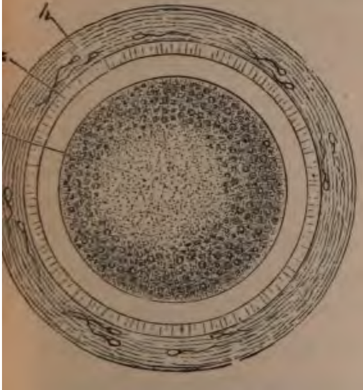


Fig. 164.—Bathybius Hæckelii (Huxley). A small piece of the formless and continually changing plasson-net of this Moneron from the Atlantic Ocean.

The origin and importance of these huge masses of living, formless plasson-bodies in the lowest depths of the sea, raises many different inquiries and thoughts. Spontaneous generation, especially, is naturally suggested by the Bathybius. We have already found that, for the origin of first Monera upon our globe, the assumption of spontaneous generation is a necessary hypothesis. We shall be all the more inclined to confirm it now that, in the Monera, we have recognized those simplest organisms, the origin of which by spontaneous generation, in the present condition of our science, no longer involves very great difficulties. For the Monera actually stand on the very boundary between organic and inorganic natural bodies.[138]

Next to the simple cytod-bodies of the Monera, as the second ancestral stage in the human pedigree (as in that of all other animals), comes the simple cell, that most undifferentiated cell-form, which, at the present time, still leads an independent solitary life, as the Amœba. For the first and oldest process of organic differentiation, which affected the homogeneous and structureless plasson-body of the Monera, caused the separation of the latter into two different substances; an inner firmer substance, the kernel, or *nucleus*, and an outer, softer substance, the cell-substance, or *protoplasma*. By this extremely important separative process, by the differentiation of the plasson into nucleus and protoplasm, the organized cell originated from the structureless cytod, the nucleolated from the non-nucleolated plastid. That the cells which first appeared upon the earth originated in this manner, by the differentiation of the Monera, is a conception which in the present condition of histological knowledge seems quite allowable; for we can even yet directly observe this oldest histological process of differentiation in Ontogeny. It will be remembered that in the egg-cell of animals, either before or after fertilization, the original kernel disappeared. We explained this phenomenon as a reversion or atavism, and assumed that the egg-cell, in accordance with the law of latent heredity, first falls back into the kernel-less, cytod stage (Fig. 165). It is only after fertilization is accomplished that a new cell-kernel arises in this cytod, which thus becomes the parent-cell (*Cytula*, Fig. 166). The transitory kernel-less cytod-condition, intermediate between the egg-cell and the parent-cell, is an interesting germ-form, because, in accordance with the fundamental law of Biogeny, it reproduces the original, oldest parent-form of the Moneron; we therefore call it the Monerula. (Cf. vol. i. pp. 178–183.)



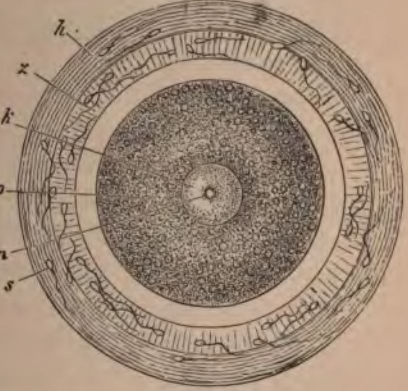
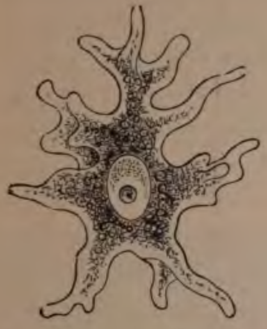


FIG. 165.—Monerula of Mammal (Rabbit). The fertilized egg-cell after the loss of the nucleus is a simple ball of protoplasm (*d*). The outer covering of the latter is formed by the modified *zona pellucida* (*z*) together with a mucous layer (*h*) secreted on to the outside of the latter. In this a few sperm-cells are still visible (*s*).

FIG. 166.—Parent-cell (*Cytula*) of a Mammal (Rabbit): *k*, parent-kernel; *n*, *nucleolus* of the latter; *p*, protoplasm of the parent-cell; *z*, modified *zona pellucida*; *s*, sperm-cells; *h*, outer albuminous covering.

We have already explained the one-celled germ-form, which we see in the original egg-cell and the parent-cell which is originated by the fertilization of the egg-cell, as the reproduction of a one-celled parent-form, to which we ascribed the organization of an Amœba (cf. Chap. VI.). For the Amœba, as it yet lives widely distributed in the fresh and salt waters of the globe, must be regarded as the most undifferentiated and most original of the various one-celled Primitive Animals. As the immature primitive egg-cells (which as "primitive eggs" or *Protova* are found in the ovary of animals) are indistinguishable from ordinary Amœbæ, we are justified in pointing to the Amœba as the one-celled phylogenetic form, which, in accordance with the fundamental law of Biogeny, is at the present time yet reproduced in the ontogenetic primitive condition of the "Amœboid egg-cell." As evidence of the striking correspondence of the two cells, it was incidentally mentioned that in the case of some Sponges the real eggs of these animals were formerly described as parasitic Amœbæ. Large one-celled Amœba-like organisms were seen creeping about in the interior of the Sponge, and were mistaken for parasites. It was only afterwards that it was discovered that these "parasitic Amœbæ" (Fig. 168) are really the eggs of the Sponge, from which the young Sponges develop. These egg-cells of the Sponge are, however, so like the true common Amœbæ (Fig. 167) in size and structure, in the nature of their nuclei and in the characteristic form of movement of their continually changing false-feet (*pseudopodia*), that, unless their source is known, it is impossible to distinguish them.

This phylogenetic explanation of the egg-cell and its reference to the primæval ancestral form of the Amœba, directly enables us to give a definite answer to the old humorous riddle: Which was first, the egg or the hen? We can



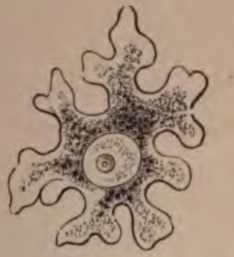


FIG. 167.—A crawling Amœba (much enlarged). The whole organism has the form-value of a simple naked cell and moves about by means of changeable processes, which are extended from the protoplasmic body and again drawn in. In the inside is the bright-coloured, roundish cell-kernel or nucleus.

FIG. 168.—Egg-cell of a Chalk-Sponge (*Olynthus*). The egg-cell creeps about in the body of the Sponge by extending variable processes, like those of the ordinary Amœba.

now very simply answer this Sphinx-question, with which our opponents try to shake or even to refute the Theory of Evolution. The egg existed much earlier than the hen. Of course it did not exist in the form of a bird's egg, but as an undifferentiated amœboid cell of the simplest form. The egg existed independently during thousands of years as a simplest one-celled organism, as the Amœba. It was only after the descendants of these one-celled Primitive Animals had developed into many-celled animal forms, and after these had sexually differentiated, that the egg, in the present physiological sense of the word, originated from the amœboid cell. Even then, the egg was first a Gastræa-egg, then a Worm-egg, then an Acrania-egg, then a Fish-egg, an Amphibian-egg, a Reptile-egg, and lastly, a Bird-egg. The egg of the Bird, as it now is, is a most complex historical product, the result of countless processes of heredity, which have occurred in the course of many millions of years.[139]

The fact that this primitive egg-form, as it first appears in the ovary of the most dissimilar animals, is always of one form, an undifferentiated cell, of the simplest amœboid character, has already been pointed out as an especially important phenomenon. In this earliest young condition, immediately after the individual egg-cell has originated in consequence of a separation of the cells of the maternal ovary, no essential difference is recognizable in the egg-cells of the most dissimilar animals. (Cf. Fig. 10, vol. i. p. 134.) It is not till later, when the primitive egg-cells, or the primitive eggs (*protova*), have absorbed different kinds of nutritive yelk, and have surrounded themselves with variously formed coverings, and in other ways differentiated—it is not till they have in this way changed into after-eggs (*metova*), that those of different classes of animals can usually be distinguished. These peculiarities of the developed after-egg, the mature egg, are naturally to be considered as only secondarily acquired, by adaptation to the different conditions of existence both of the egg itself and of the animal which forms the egg.

The two first and oldest ancestral forms of the human race, which we have now considered, the Moneron and the Amœba, are, considered from a morphological point of view, simple organisms and individuals of the first order, Plastids. All subsequent stages in the ancestral chain are, on the other hand, compound organisms or individuals of higher order—social aggregations of a number of cells. The earliest of these, which, under the name of Synamœbæ, we must rank as the third stage of our pedigree, are quite simple societies of all homogeneous undifferentiated cells; amœboid communities. To be certain as to their nature and origin, we need only trace the ontogenetic product of the parent-cell step by step. After the cytula (Fig. 166) has originated, by the re-formation of a cell-kernel, from the Morula (Fig. 165), the parent-cell breaks up, by repeated division, into numerous cells. We have already minutely examined this important process of egg-cleavage, and have found that all the various modes of the latter are modifications of a single mode, that of original or primordial cleavage. (Cf. Chap. VIII., p. 188.) In the Vertebrate line this palingenetic form of egg-cleavage has been accurately re-

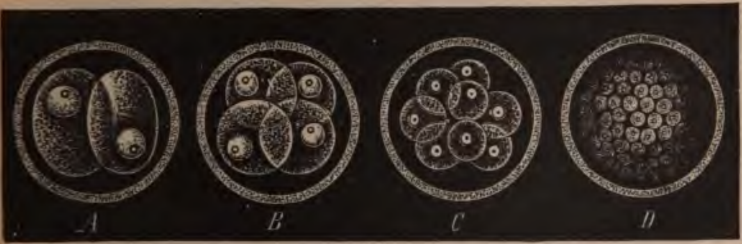


FIG. 169.—Original or primordial egg-cleavage. The parent-cell, or cytula, which resulted from the fertilization of the egg-cell, first breaks up, by a continuous and regular process of division, into two cells (*A*), then into four (*B*), then into eight (*C*), and, lastly, into very numerous cleavage-cells (*D*).

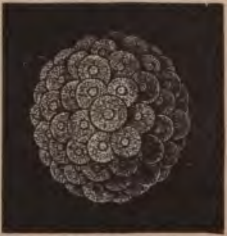


FIG. 170.—Mulberry-germ, or morula.

tained to the present time only by the Amphioxus, while all other Vertebrates have assumed a modified kenogenetic form of cleavage. (Cf. Table III., vol. i. p. 241.) The latter certainly originated at a later period than the former, and the egg-cleavage of the Amphioxus is, therefore, extremely interesting (vol. i. p. 442). In this the parent-cell first parts into two similar cells, the two first cleavage-cells (Fig. 169, *A*). From these, by continuous division, arise 4, 8, 16, 32, 64 cells, etc., etc. (Fig. 169). The final result of this primordial cleavage was, we found, the formation of a globular mass of cells, which was entirely composed of homogeneous, undifferentiated cells of the simplest character (Figs. 170, and 171, *E*). On account of the resemblance which this globular mass of cells bears to a mulberry or blackberry, we called it the "mulberry-germ," or *morula*.

This "morula" evidently at the present day shows us the many-celled animal body in the same entirely simple primitive condition in which, in the earlier Laurentian primitive epoch, it first originated from the one-celled amœboid primitive animal form. The morula reproduces, in accordance with the fundamental law of Biogeny, the ancestral form of the Synamœba. For the first cell-communities, which then formed, and which laid the first foundation of the higher many-celled animal body, must have consisted entirely of homogeneous and quite simple amœboid cells. The earliest Amœbæ lived isolated hermit lives, and the amœboid cells, which originated from the division of these one-celled organisms, must also have long lived isolated and self-dependent lives. Gradually, however, by the side of these one-celled Primitive Animals, small amœboid communities arose, owing to the fact that the

GERMINATION OF A CORAL.

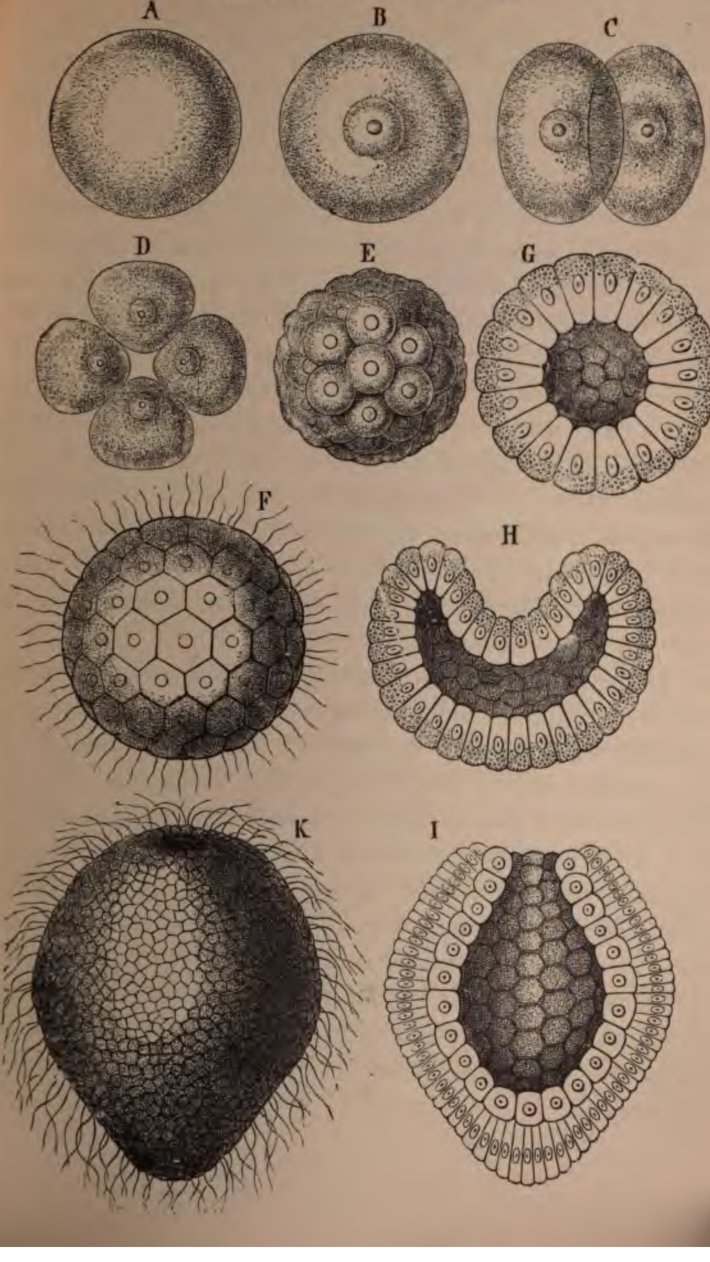


FIG. 171.—Germination of a coral (*Monoxenia Darwinii*): *A*, monerula; *B*, parent-cell (*cytula*); *C*, two cleavage-cells; *D*, four cleavage-cells; *E*, mulberry-germ (*morula*); *F*, vesicular germ (*blastula*); *G*, vesicular germ in section; *H*, infolded vesicular germ in section; *I*, gastrula in longitudinal section; *K*, gastrula, or cup-germ, seen from the outside.

kindred cells which originated through division remained united. The advantages which these first cell-societies had in the struggle for existence over the solitary hermit cell must have favoured their progression, and have encouraged further development. Yet even at the present time several genera of Primitive Animals live in the sea and in fresh water, and permanently represent these primitive cell-communities in their simplest form. Such, for instance, are several species of *Cystophrys* described by Archer, the Rhizopods described by Richard Hertwig under the name of *Microgromia socialis*, and the *Labyrinthulæ* which were discovered by Cienkowski; formless masses of homogeneous and quite simple cells.[140]

In order to recognize the ancestors of the human races which developed first phylogenetically from the Synamœba, we need only continue to trace the ontogenetic modification of the Amphioxus-morula in the next stages. The first thing noticed is that a watery fluid collects within the solid globular cell-mass, and the cells are forced together and driven out to the periphery of the body (Fig. 171, *F*, *G*; Plate X. Fig. 9). The solid mulberry-germ thus changes into a simple hollow globe, the wall of which is formed of a single cell-stratum. This cell-stratum we called the germ-membrane (*blastoderma*), and the hollow globe the germ-membrane vesicle (*blastula*, or *blastosphæra*).

The interesting blastula germ-form is also of great significance, for the modification of the mulberry-germ into the germ-membrane vesicle takes place in the same way in a great many animals of very dissimilar tribes; for instance, in many Plant-animals and Worms, in the Ascidians, in many Star-animals (*Echinoderma*) and Soft-bodied Animals (*Mollusca*), and also in the Amphioxus. In those animals, however, in the ontogeny of which there is no real palingenetic blastula, this deficiency is evidently only the result of kenogenetic causes, of the formation of a nutritive yelk; and of other conditions of embryonic adaptation. We may therefore assume that the ontogenetic blastula is the reproduction of a primæval phylogenetic ancestral form, and that all animals (with the exception of the lower Primitive Animals) have originated from a common parent-form, the structure of which was essentially that of a germ-membrane vesicle. In many lower animals, the evolution of the blastula takes place not within the egg-coverings, but outside this, free in water. Very soon after this, each cell of the germ-membrane begins to extend one or more movable, hair-like protoplasmic processes; owing to the fact that these cilia or whips vibrate in the water the whole body swims about (Fig. 171, *F*). This vesicular larva, the body-wall of which forms a cell-stratum, and which rotates and swims by means of the united vibrations of the cilia, has, ever since the year 1847, been called the planula, or ciliated larva. This designation, is, however, used by different zoologists in different senses, and the gastrula, of which we shall speak presently, has, especially, often been confused with the planula. It is, therefore, more convenient to call the true planula-form the blastula.

Various kinds of Primitive Animals, which yet exist both in the sea and in fresh water, are formed essentially like the blastula, and which, in a certain sense, may be considered as permanent or persistent blastula-forms, hollow vesicles, the wall of which is formed of a single stratum of ciliated homogeneous cells. These Planæads, or Blastæads, as they may be called, are formed in the very mixed society of the Flagellatæ, especially the Volvoces (for instance, *Synura*). I noticed in September, 1869, on the Island Gis-Oe, on the coast of Norway, another very interesting form, which I named *Magosphæra planula* (Figs. 172, 173). The fully developed body of this forms a globular vesicle, the wall of which is composed of from thirty to forty vibratory homogeneous cells, and which swims about freely in the sea. Afte

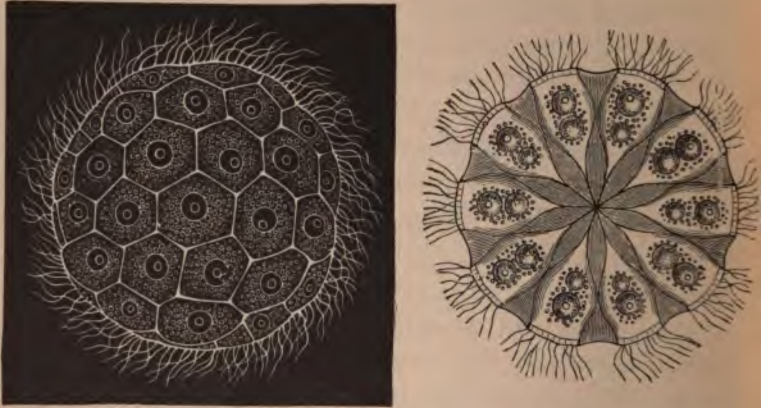


FIG. 172.—The Norwegian Flimmer-ball (*Magosphæra planula*), swimming by means of its vibratile fringes; seen from the surface.

FIG. 173.—The same, in section. The pear-shaped cells are seen bound together in the centre of the gelatinous sphere by a thread-like process. Each cell contains both a kernel and a contractile vesicle.

having reached maturity the society dissolves. Each separate cell still lives a while independently, grows, and changes into a crawling Amœba. This afterwards assumes a globular form, and encases itself by exuding a structureless integument. The cell now has just the appearance of a common animal egg. After it has remained for a time in this quiescent state, the cell breaks up, by means of continued division, first into 2, then into 4, 8, 16, 32 cells. These again arrange themselves so as to form a globular vesicle, put forth cilia, and bursting the encasing integument, swim about in the same Magosphæra-form from which we started. This accomplishes the entire life-history of this remarkable Primitive Animal.[141]

If we compare these permanent blastula-forms with the freely swimming Flimmer-larvæ or planula-condition, of similar structure, of many other lower animals, we may with certainty infer therefrom the former existence of a primæval and long-extinct parent-form, the structure of which was essentially like that of the planula or blastula. We will call this the Planæa, or Blastæa. The whole body, in its fully developed condition, consisted of a simple hollow globe, filled with fluid or structureless jelly, the wall of which formed a single stratum of homogeneous cells, covered with cilia. Many different kinds and species of Planæa-like Primitive Animals must certainly have existed and formed a distinct class of Protozoa, which we may call Flimmer-swimmers (*Planæada*). A remarkable proof of the natural philosophical genius with which Karl Ernst Baer penetrated into the deepest secrets of the history of animal evolution, is that, as early as the year 1828 (ten years before the cell-theory was established), he guessed the significance of the blastosphæra, and, truly prophetically, insisted upon it in his classical "Entwickelungsgeschichte der Thiere" (vol. i. p. 223). The passage in question says: "The further back we go in evolution, the more do we find a correspondence in very different animals. This leads us to the question: Are not all animals in the beginning of their evolution essentially alike, and is there not a primary form common to all? As the germ is the undeveloped animal itself, it is not without reason that it is asserted that the simple vesicular form is the common primitive form from which all animals, not only ideally, but also historically, develop." This latter sentence has not only ontogenetic, but also phylogenetic significance, and is all the more noteworthy because the blastula of the most diverse animals, and the constitution of its wall of a single cell-stratum, was not then known. And yet Baer, in spite of the extreme deficiency of his empiric grounds, ventured the bold statement: "At their first appearance all animals are perhaps alike, and are merely hollow globes."

Next to the primæval ancestral form of the Planæa, as the fifth stage in the human pedigree, is the Gastræa, a form which arises from the Planæa. Of all ancestral forms this, as we have already shown, is of pre-eminent philosophical significance. Its former existence is certainly proved by the very important gastrula, which is met with as a transitory germ-stage in the ontogeny of the most various animals (Fig. 171, *I*, *K*). We found that the gastrula, in its original, palingenetic form, is a globular, oval or oblong-round body, with one axis which has a simple cavity with one opening (at one pole of the axis). This is the primitive intestinal cavity with its mouth-opening. The intestinal wall consists of two cell-strata, which are, in fact, the two primary germ-layers, the animal skin-layer, and the vegetative intestinal layer.

The ontogenetic origin of the gastrula from the blastula at the present day affords us trustworthy intelligence as to the phylogenetic origin of the Gastræa from the Planæa. We found that on one side of the globular germ-membrane vesicle a groove-like depression begins, and this inversion (*invaginatio*) becomes continually deeper (Fig. 171, *II*). At last it is so great, that the outer, inverted part of the germ-membrane, or blastoderm, attaches itself closely to the inner, uninverted portion (Fig. 171, *I*). Now, if guided by this ontogenetic process, we wish to conceive the phylogenetic origin of the Gastræa in accordance with the fundamental law of Biogeny, we must imagine that the one-layered cell-society of the globular Planæa began, especially at one point of its surface, to absorb nourishment. At the nutritive point on the surface of the ball a groove-like depression was gradually formed by natural selection. The groove, which was at first quite shallow, in course of time became continually deeper. The function of nourishing, of absorption of nutriment, and digestion, was soon limited to the cells which lined the groove, while the other cells undertook the function of movement and covering. Thus originated the first division of labour among the originally homogeneous cells of the Planæa.

The first result of this earliest histological differentiation was the distinction of two different kinds of cells; within the hollow the nutritive cells, without, on the surface, the motive or locomotive cells. The distinction of the two primary germ-layers was thus caused. The inner cells of the hollow formed the inner or vegetative layer, accomplishing the functions of nutrition; the outer cells of the covering formed the outer or animal layer, exercising the functions of locomotion and covering the body. This first and oldest process of differentiation is of such fundamental significance that it deserves the deepest thought. When we consider that the body of the human being, with all its different parts, and also the body of all other higher animals, originates from these two simple primary germ-layers, we cannot over-estimate the phylogenetic significance of the gastrula. For in the quite simple primitive intestine, or the primitive intestinal cavity of the gastrula and its simple mouth-opening, the first real organ of the animal body, in a morphological sense, is gained; the earliest genuine organ, from which all the other organs have differentiated at a later period. The whole body of the gastrula is really only a "primitive intestine."

We have already pointed out the remarkable agreement between the palingenetic gastrula-forms of animals of the most diverse classes; of Sponges (Fig. 174, *A*), Polyps, Corals (Fig. 171, *I*), Medusæ, Worms (Fig. 175, *B*) Star-animals (*Echinoderma*, *C*), Articulated Animals (*Arthropoda*, *D*), Soft-bodied Animals (*Mollusca*, *E*), and Vertebrates (*F*). All these various forms of the palingenetic gastrula are much alike, and are only distinguished by such unessential and subordinate peculiarities, that the systematic zoologist, in his "natural system," could only represent them as different species of a single genus. The various kenogenetic gastrula-forms which have been described were also referable to that original palingenetic form (vol. i. p. 231). The gastrula proved to be a germ-form common to all classes of animals, with the exception of the Protozoa. This highly important fact justifies the inference in accordance with the fundamental law of Biogeny, that the various ancestral

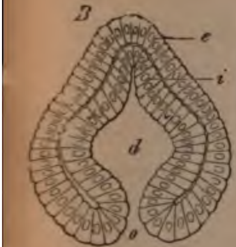


FIG. 175.

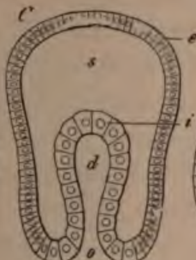


FIG. 176.

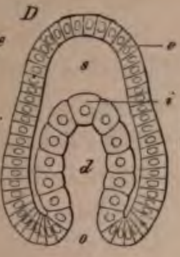


FIG. 177.

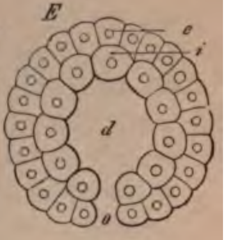


FIG. 178.

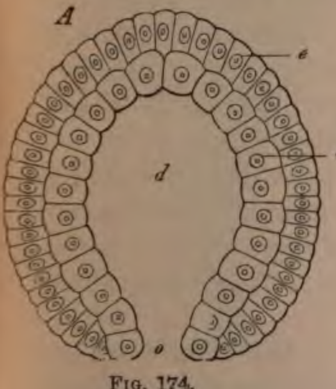


FIG. 174.

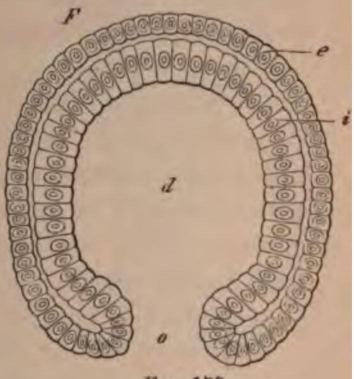


FIG. 179.

FIG. 174.—(*A*) Gastrula of a Zoophyte (*Gastrophysema*), Haeckel.

FIG. 175.—(*B*) Gastrula of a Worm (Arrow-worm, *Sagitta*). After Kowalevsky.

FIG. 176.—(*C*) Gastrula of an Echinoderm (Star-fish, *Uraster*). After Alexander Agassiz.

FIG. 177.—(*D*) Gastrula of an Arthropod (Primitive Crab, *Nauplius*).

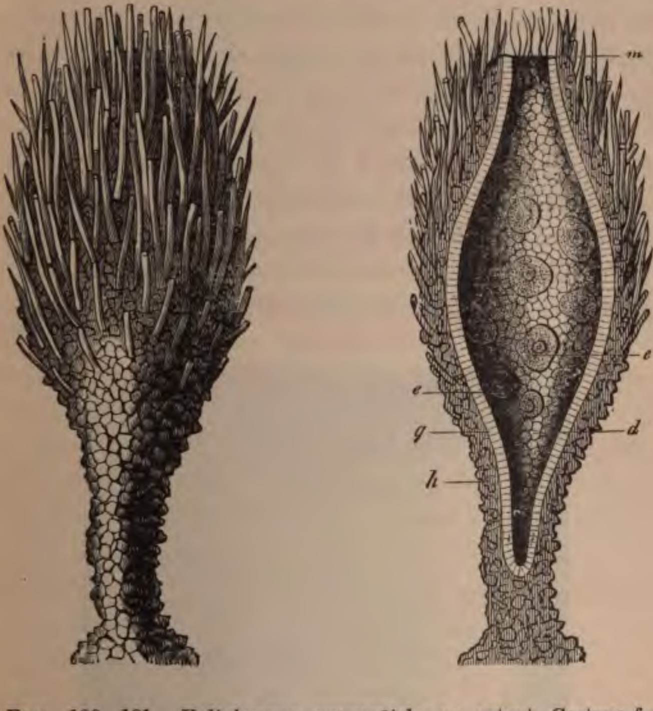
FIG. 178.—(*E*) Gastrula of a Mollusc (Pond-snail, *Limnæus*). After Karl Rabl.

FIG. 179.—(*F*) Gastrula of a Vertebrate (Lancelet, *Amphioxus*) After Kowalevsky.

lines of all these classes of animals have developed phylogenetically from the same parent-form. This most significant primæval parent-form is the Gastræa.

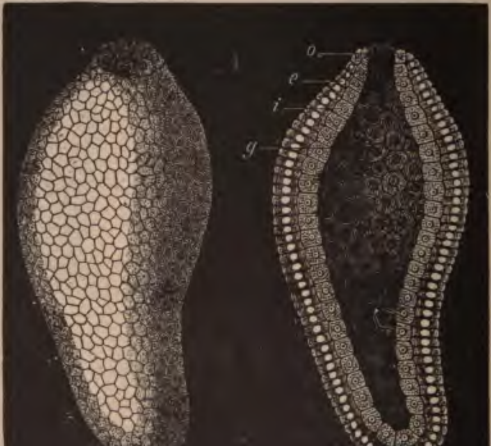
The Gastrea was at any rate already present in the sea during the Laurentian period, and by means of its vibratory fringe hurried about in the water, just like the yet extant free-moving ciliated gastrulæ of this age. Probably the primæval Gastræa, which has been extinct for many millions of years, differed from the living gastrula of the present day only in some unessential point. On grounds derived from Comparative Anatomy and Ontogeny, the explanation of which would lead us too far, we may assume that the Gastræa had already acquired sexual reproduction, and did not only propagate its species asexually (by division—bud-formation or spore-formation), as was probably the case with the four preceding ancestral stages. Presumably, single cells of the primary germ-layers assumed the character of egg-cells, others that of fertilizing seed-cells. (Cf. Chapter XXV.) This hypothesis is founded on the fact that sexual reproduction is yet met with in the same simple forms in the lowest Plant-Animals (*Zoophyta*), especially in the Sponges.

Two small animal forms are especially interesting in their bearing on this aspect of the Gastræa theory. They have as yet been little observed, but of all extant animals they are most nearly allied to the primæval Gastræa, and may therefore be called "the Gastræads of the present day."[142] One of these animals, *Haliphysema* (Figs 180 and 181), has been described by Bowerbank as a Sponge; the other, *Gastrophysema*, by Carter as a Rhizopod (as "Squamulina"). The entire mature body of the developed person of *Haliphysema* forms a most simple, cylindrical or egg-shaped pouch, the wall of which consists of two cell-strata. The cavity of the pouch is the stomach-cavity, and the



Figs. 180, 181.—*Haliphysema primordiale*, an extant Gastræa-form. Fig. 180. External view of the whole spindle-shaped animal (attached by its foot to seaweed). Fig. 181. Longitudinal section of the same. The primitive intestine (*d*) opens at its upper end in the primitive mouth (*m*). Between the whip-cells (*g*) lie amœboid eggs (*e*). The skin-layer (*h*) below is encrusted with grains of sand, above with sponge-spicules.

opening at the top is the mouth-opening (Fig. 181, *m*). The two cell-strata forming the wall of the pouch are the two primary germ-layers. These most simple Plant-Animals differ from the gastrula principally in the fact that the former are attached by one end (that opposite to the mouth-opening) to the bottom of the sea, while the latter are free. Moreover, the cells of the skin-layer are coalescent and have included many foreign bodies, such as sponge-spicules, sand-grains, etc., which serve to support the body-wall (Fig. 180). The intestinal layer, on the other hand, consists merely of a stratum of ciliated cells (Fig 181, *d*). When the *Haliphysema* is sexually mature, individual cells of its entoderm assume the character of female egg-cells; on the other hand, individual cells of its exoderm become male seed-cells; the fertilization of the former by the latter



FIGS. 182, 183.—Ascula of a Sponge (*Olynthus*). Fig. 182, from the outside; Fig. 183, in longitudinal section: *g*, primitive intestine; *o*, primitive mouth; *i*, intestinal layer; *e*, skin-layer.

takes place directly through the stomach-cavity. A true palingenetic gastrula (Fig. 174) develops, just as in the Monoxenia (Fig. 171), from the fertilized egg. This swims about for a time in the sea, then attaches itself, and in this state resembles a simple young-form, which occurs in the course of the evolution of many other Plant-Animals, and which is called the ascula (Figs. 182, 183). In consequence of the absorption of foreign bodies by the exoderm, it becomes the *Haliphysema.*

When we consider that there is no other important difference between the free-swimming gastrula and this attached, simplest Plant-animal, we are fairly justified in stating that in the simplest form of Gastræa sexual reproduction must have taken place in the same way. In the Gastræads, just as in Plant-animals, both kinds of sexual cells—egg-cells and sperm-cells—must have formed in the same person; the oldest Gastræads must, therefore, have been hermaphrodite. For Comparative Anatomy shows that hermaphroditism, that is, the union of both kinds of sexual cells in one individual, is the oldest and original condition of sexual differentiation; the separation of the sexes (*Gonochorismus*) did not originate till a later period.

TABLE XVII.

Systematic Survey of the five earliest evolutionary stages of the Human Ancestral Line, compared with the five earliest stages of Individual and of Systematic Evolution.

Form-Value. Of the five earliest stages of the animal body.	**Phylogeny.** The five earliest stages in the evolution of the tribe.	**Ontogeny.** The five earliest stages in the evolution of the germ.	**The System.** The five earlies stages in the anima system.
1. *First Stage.* A quite simple **cytod** (a non-nucleated plastid).	1. **Monera.** The oldest animal Monera (originating by spontaneous generation).	**1.** **Monerula.** A non-nucleated animal-egg (after fertilization and after loss of the germ-vesicle).	1. **Monera.** Protamœba, Bathybius, and other extan Monera.
2. *Second Stage.* A simple cell (a nucleated plastid).	2. **Amœba.** Oldest animal Amœba.	2. **Cytula.** A nucleated, fertilized animal-egg ("first cleavage globule").	2. **Amœba.** Extant Amœba.
3. *Third Stage.* A quite simple aggregation of simple, similar cells.	3. **Synamœba.** The oldest aggregation of animal Amœbæ.	3. **Morula.** "*Mulberry-germ.*" A globular mass of cleavage-cells.	3. **Labyrinthula.** A mass of similar, one-celled primitive animals.
4. *Fourth Stage.* A simple hollow globe, filled with liquid, the wall of which consists of a single stratum of homogeneous cells.	4. **Planæa.** An animal hollow globe, the wall of which consists of a single stratum of ciliated cells. (*blastæa.*)	4. **Blastula.** A hollow globe, the wall of which consists of a single stratum of homogeneous cells (the Planula of lower animals). (*blastosphæra.*)	4. **Magosphæra.** A hollow globe, the wall of which consists of a single stratum of homogeneous ciliated cells.
5. *Fifth Stage.* A hollow body, with a single axis, the wall of which consists of different cell-strata; with an opening at one pole of the axis.	5. **Gastræa.** Parent-form of intestinal animals, or *Metazoa*. Simple primitive intestine with primitive mouth. The body-wall is formed by the exoderm and the entoderm.	5. **Gastrula.** Intestinal larva. A simple intestinal cavity with a mouth-opening. The body-wall is formed by the two primary germ-layers.	5. **Haliphysema.** A quite simple plant-animal. An unarticulated uniaxial person, the body-wall of which consists of the exoderm and the entoderm.

CHAPTER XVII.

THE ANCESTRAL SERIES OF MAN.

II. FROM THE PRIMITIVE WORM TO THE SKULLED ANIMAL.

The Four Higher Animal Tribes are descended from the Worm Tribe.—The Descendants of the Gastræa; in one direction the Parent Form of Plant-Animals (Sponges and Sea-Nettles), in the other the Parent Form of Worms.—Radiate form of the former, Bilateral form of the latter.—The Two Main Divisions of the Worms, Acœlomi and Cœlomati: the former without, the latter with, a Body Cavity and Blood vessel System.—Sixth Ancestral Stage: Archelminthes, most nearly allied to Turbellaria.—Descent of the Cœlomati from the Acœlomi.—Mantled Animals (*Tunicata*) and Chorda-Animals (*Chordonia*).—Seventh Stage: Soft-Worms (*Scolecida*).—A Side Branch of the latter: the Acorn-Worm (*Balanoglossus*).—Differentiation of the Intestinal Tube into Gill-intestine and Stomach-intestine.—Eighth Stage: Chorda-Animals (*Chordonia*).—Ascidian Larva exhibits the Outline of a Chorda-Animal.—Construction of the Notochord.—Mantled Animals and Vertebrates as Diverging Branches of Chorda-Animals.—Separation of Vertebrates from the other Higher Animal Tribes (Articulated Animals, Star-Animals, Soft-bodied Animals).—Significance of the Metameric Formation.—Skull-less Animals (*Acrania*) and Skulled Animals (*Craniota*).—Ninth Ancestral Stage: Skull-less Animals.—Amphioxus and Primitive Vertebrate.—Development of Skulled Animals (Construction of the Head, Skull, and Brain).—Tenth Ancestral Stage: Skulled Animals, allied to the Cyclostomi (*Myxinoidæ* and *Petromyzonidæ*).

"Not like the gods am I! Full well I know;
But like the worm which in the dust must go,
And, finding in the dust his life and weal,
Is crushed and buried by the traveller's heel.—

> Why dost thou grin at me, thou hollow skull?
> As though of old thy brain, like mine, was vexed,
> Had looked to find bright day, but in the twilight dull,
> In search for truth, was sad and sore perplexed!"
>
> GOETHE.

BOTH in prose and in poetry man is very often compared to a worm. "A miserable worm," "a poor worm," are common and almost compassionate phrases. If we cannot detect any deep phylogenetic reference in this zoological metaphor, we might at least safely assert that it contains an unconscious comparison with a low condition of animal development which is interesting in its bearing on the pedigree of the human race. For there is no doubt that the vertebrate tribe, in common with those of the other higher classes of animals, have developed phylogenetically from that multiform group of lower invertebrate animals which are now called Worms. However closely we limit the zoological significance of the word "Worm," it yet remains indubitable that a large number of extinct Worms must be reckoned among the direct ancestors of the human race.

The group of Worms (*Vermes*) is much more limited in the Zoology of the present day, than was the same class in the older Zoology, which followed the system of Linnæus. It, however, yet includes a great number of very diverse lower animals, which, phylogenetically, we may regard as the few last living twigs of an immense spreading tree, the trunk and main branches of which have for the most part long since died off. On the one side, among the widely divergent classes of Worms, are found the parent-forms of the four higher tribes of animals, the Molluscs, Star-animals, Articulates, and Vertebrates; on the other side, several comprehensive groups and also single isolated genera of Worms are to be regarded as root-suckers which have sprouted directly from the rest of the primæval family-tree of the Worms. Some of these suckers have evidently changed but little from the long-extinct parent-form, the Primitive Worm (*Prothelmis*), which is immediately connected with the Gastræa.

Comparative Anatomy and Ontogeny clearly and significantly prove that the Gastræa must be regarded as the direct ancestor of this Primitive Worm. Even now, a gastrula develops from the egg of all Worms after its cleavage. The lowest and most imperfect Worms retain throughout life an organization so simple that they are but little raised above the lowest Plant-animals, which are also immediate descendants of the Gastræa, and which also yet develop directly from the gastrula. If the genealogical relation of these two lower animal tribes, the Worms and the Plant-animals, is closely examined, it becomes evident that the most probable hypothesis of their descent is, that the two originated, as independent branches, directly from the Gastræa. On the one side, the common parent-form of the Worms developed from the Gastræa; as, on the other side, did the common parent-form of the Plant-animals. (Cf. Tables XVIII. and XIX.)

The tribe of Plant-animals (*Zoophytes*, or *Cœlenterata*) now comprehends, on the one side, the main class of Sponges (*Spongiæ*); on the other, the main class of the Sea-nettles (*Acalephæ*); to the former belong the Gastræads and Poriferæ, to the latter the Hydroid-polyps, the Medusæ, Ctenophoræ, and Corals. From the Comparative Anatomy and the Ontogeny of these we may infer, with great probability, that all these Plant-animals descend from a common and very simple parent-form, the structure of which resembled that of the ascula in essential points (Figs. 182, 183, p. 68). The uniaxial outline of the ascula and the gastrula is usually retained by the Sponges, while in most Sea-nettles (*Acalephæ*) transverse axes have been differentiated in the course of further evolution, thus giving rise to a characteristic radiate structure with a pyramidal general outline.

In distinction from this predominant radiate outline of Plant-animals, a marked bilateral general outline is developed from the first in the second offshoot from the gastrula, in the Worms. As the radiate form is marked by adaptation to an adherent mode of life, so is the bilateral form by adaptation to certain definite acts of free locomotion. The constant direction and carriage of the body which would be maintained in this mode of free locomotion, conditioned the two-sided, or bilateral outline of the symmetrical Worms. Even the parent-form of the latter, the Primitive Worm (*Prothelmis*) must have acquired this character, and thus have become distinguished from the uniaxial parent-form of the Plant-animals. In this simple mechanical impetus, in the defined free locomotion of the Worms, on the one hand, and in the stationary mode of life of the earliest Plant-animals on the other, we must look for the efficient cause which produced in the one the bilateral or two-sided, in the other the radiate outline of the body. The former, the bilateral outline, has been inherited by the human race from the Worms.

Except through the Gastræa, the common parent-form of Plant-animals and Worms, the human race is, therefore, not related to the Plant-animals. It will be our next task to consider more closely the pedigree of Man in so far as it coincides with that of the Worms. Let us examine how far the Comparative Anatomy and Ontogeny of Worms justify us in looking among the latter for primæval ancestors of Vertebrates, and therefore of Man. For this end we must first consider the zoological system of Worms. In accordance with the most recent investigations of the Comparative Anatomy and Ontogeny of Worms, we divide (without reference to the many and various peculiarities of the numerous separate classes, which in this place do not interest us) the whole mass of forms within this tribe into two large main groups. The first main group, which we call Bloodless Worms (*Acœlomi*), comprehends the earlier division of the lower Worms, which have no true body-cavity, no system of blood-vessels, no heart, no blood, —in short, none of the parts connected with this organ-system. The second main group, on the contrary, called Blood-worms (*Cœlomati*), are distinguished from the former by the possession of a true body-cavity, and also by the presence of a blood-like fluid, which fills this cavity; most of them also develop special blood-vessels, which again cause further correlated advances in structure. The relation of these two main groups of Worms is very evidently phylogenetic. The Acœlomi, which are very nearly allied to the Gastræa and the Plant-animals, are to be regarded as an earlier and lower group, from which the more recent and higher division of the Cœlomati developed, perhaps towards the end of the Laurentian Period.

We will first carefully examine the lower group of Worms, the Acœlomi, among which we must look for the sixth ancestral stage of the human race, the stage immediately following the gastrula. The name "Accœlomi" signifies "Worms without a body-cavity, or cœloma," and therefore without blood, or vascular system. The extant Accœlomi are generally included in a single class, which, on account of their flattened bodies, are called Flat-worms (*Plathelminthes*). To this class belong the Gliding-worms (*Turbellaria*), which live independently in the water; also the parasitic intestinal Sucking-worms (*Trematoda*), and the Tape-worms (*Cestoda*), which have become yet more degraded by parasitism. The phylogenetic relations of the three forms of Flat-worms are very evident; the Sucking-worms originated from the free Gliding-worms by adaptation to a parasitic mode of life; and, by a yet more completely parasitic life, the Tape-worms originated from the Sucking-worms. These are striking examples of the gradually increasing degeneration of the most important organs.

In addition to these well-known extant Flat-worms, great numbers of other Accœlomi must have lived during the Archilithic Epoch, which in general form were very much like those of the present day, but were, in some respects, yet more simply organized, and were, in their lowest stages of development, immediately connected with the Gastræads. The whole of these lowest Accœlomi, among which the common parent-form of the whole Worm tribe (the *Prothelmis*) must have been, may be classed as "Primitive Worms" (*Archelminthes*).

The two classes of the Accœlomi, the Primitive Worms and the Flat-worms, represent in their external form the simplest bilateral condition of the animal body. The body is a simple oval, usually somewhat flattened, without any appendage (Figs. 184, 185). The dorsal side of the leaf-like body differs from the ventral side, on which the Worm creeps. Accordingly, even in these most simple Worms there are the three definite axes which mark the bilateral type-form, and which re-occur in the human body and in that of all higher animals: (1) a longitudinal axis (main axis), which passes from front to rear; (2) a lateral axis, passing from right to left; and (3) a sagittal axis, passing from the dorsal to the ventral surface. (Cf. vol. i. p. 257.) This so-called symmetrical or "bilateral" arrangement of the outline of the body is simply the mechanical result of adaptation to a creeping form of locomotion, during which one end of the body is always directed forwards. The geometric outline of the gastrula, as of the ascula, has but one axis with unequal poles (*Monaxonia diplopola*). The typical outline of Worms, as of Vertebrates, is, on the contrary, bilateral, with tranverse axes (*Stauraxonia dipleura*).[144]

The whole outer surface of the Gliding-worms (*Turbellaria*) is covered, as in the gastrula, with a thick, fine ciliated coat; that is, with a fur-like covering of extremely fine and close microscopic hairs, which are direct processes of the uppermost cells of the epidermis, and maintain an uninterrupted whirling or vibratory motion (Fig. 184, *f*). The constant vibrations of these cilia cause a continued current of water over the surface of the body. Fresh water is constantly conveyed to the surface of the skin by this current, thus permitting respiration in its simplest form (skin-respiration). A similar ciliated covering, just as is seen in the extant Gliding-worms of our fresh-water seas, presumably covered our extinct ancestors of the Primitive

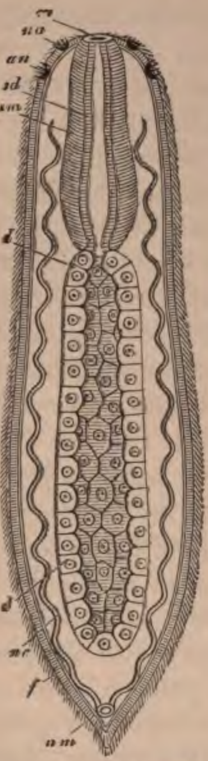
Worm group, the *Archelminthes*. They inherited this ciliated dress directly from the Gastræa.

If we now make various vertical sections (longitudinal and transverse) through the simple body of the Gliding-worms (and that of the *Archelminthes* which are certainly very closely allied to the former), we soon discover that their internal structure is considerably higher than that of the Gastræads. We first observe that the two primary germ-layers (inherited from the Gastræa) have differentiated into several cell-strata. The skin-layer and the intestinal layer have each split into two strata. The four secondary germ-layers, which are thus produced, are the same that we found resulted from the first differentiation of the two primary germ-layers in the embryo of the Vertebrate also. (Cf. the transverse sections through the larval Amphioxus and Earth-worm, Figs. 50 and 51, p. 236, and Plate IV. Fig. 2; Plate V. Fig. 10.)

The highly important histological differentiation of these four secondary germ-layers led directly to further organological processes of differentiation, by which the organism of the Primitive Worms was soon considerably raised above that of the Gastræads. In the latter there was really, in a morphological sense, but a single organ, the primitive intestine, with its mouth-opening. The whole body was nothing but an intestinal canal; the intestinal wall was at the same time the wall of the body. Of the two cell-layers, forming this intestinal wall, the inner accomplished the functions of nutrition, the outer those of motion and covering. As some of the cells of the primary germ-layers developed into egg-cells, and others into sperm-cells, these layers also performed the function of reproduction. In the

Primitive Worms, however, simultaneously with the formation of the secondary germ-layers, these various functions also began to be distributed to various organs, which detached themselves from the original main organ, the primitive intestine. Special organs originated for reproduction (sexual glands), for secretion (kidneys), for motion (muscles), and for sensation (nerves and sense-organs).

In order to obtain an approximate picture of the simplest form in which all these various organs first appeared in the Primitive Worms, it is only necessary to examine the most imperfect forms of Gliding-worms (*Turbellaria*), as they exist at the present time in salt and fresh water. They are mostly very small and insignificant Worms of the simplest form, many being scarcely a millimetre or a few millimetres in length. In the simplest species of Gliding-worms the greater part of the oval body is occupied by the intestinal canal. This is a very regularly shaped pouch with an opening, representing both mouth and anus (Fig. 184, *m*). At the anterior section of the intestinal tube, which is separated as a throat (*pharynx*, *sd*), the fibrous layer is very thick, a thick muscular layer. Immediately outside the intestinal-fibrous layer lies the skin-fibrous layer, which in most worms appears as a large skin-muscle sac. Above the throat in Gliding-worms a nerve system of the simplest form is already visible in front, a pair of small nerve-knots, or ganglia, which from their position are called the "upper throat ganglia," or "brain" (Fig. 185, *g*). Delicate nerve-threads (*n*) pass from this to the muscles and to the ciliated skin-sensory layer. A pair of quite simple eyes (*au*) and nose-pits (*na*) are to be found in a few Gliding-worms. The Flat-worms are also universally provided with a pair of simple kidney-canals ("excretory organs"), the form of two long, thin, glandular tubes, which traver the right and left sides of the intestine and open at th hinder end of the body (Fig. 184, *nm*). We found that th



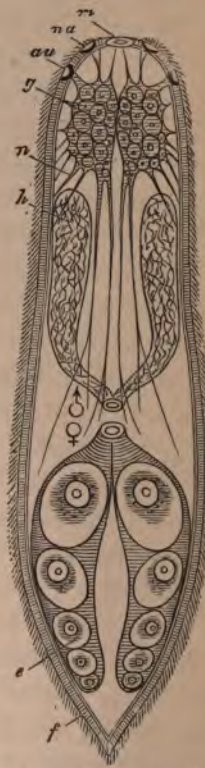


FIG. 184.—A simple Gliding-worm (*Rhabdocœlum*): *m*, mouth; *sd*, throat epithelium; *sm*, throat-muscles; *d*, stomach-intestine; *nc*, kidney ducts *nm*, opening of the kidneys; *au*, eye; *na*, nose-pit.

FIG. 185.—The same Gliding-worm, showing the remaining organs: brain; *au*, eye; *na*, nose-pit; *n*, nerves; *h*, testes; ♂, male opening ♀, female opening; *e*, ovary; *f*, ciliated outer-skin.

two primitive kidney canals in the vertebrate embryo also appeared at a very early period, shortly after the first differentiation of the middle germ-layer (*mesoderma*). The appearance of these at so early a period shows that the kidneys are very important primordial organs. It also shows their universal existence in all Flat-worms; for even the Tape-worms, which, in consequence of the adoption of a parasitic mode of life, have lost the intestine, yet have the two secreting primitive kidneys, or "excretory ducts." The latter seem, therefore, to be older and of greater physiological importance than the blood-vessel system, which is wholly wanting in the Flat-worms. The sexual organs appear in many of the Gliding-worms in a very complex form; while in others their form is very simple. Most of them are hermaphrodites; that is, each individual worm has both male and female sexual organs. In the simplest forms we find a testis in the anterior part (Fig. 185, *h*), a single or double ovary behind (*a*). One of these simplest existing Acœlomi, such as we find among the lowest Rhabdocœla, may give us an approximate idea of the structure of the Primitive Worm, which forms the sixth stage in the human pedigree.

These ancestors of the human race, which, on account of their general organization, must be placed among the Bloodless Worms (*Acœlomi*), must have been represented during the Archilithic Epoch by a large number of various Worm forms. The lowest of these must have been directly connected with the Gastræads (the fifth ancestral stage); the most highly developed must, on the other hand, have been directly connected with the Cœlomati (the seventh stage). As, however, our present knowledge of the Comparative

Anatomy and Ontogeny of the Accœlomi is very fragmentary, and much too imperfect to enable us to point with certainty to the series of the various stages, we will not attempt a detailed arrangement of them. We will turn instead to the seventh stage in the human pedigree, which belonged to the multiform group of the Blood-bearing Worms (*Cœlomati*).

The great organic advance in structure by which the Blood-bearing worms, or Cœlomati, developed from the older Bloodless Worms, or Accœlomi, consisted in the formation of a body-cavity (*cœloma*), and of a nutritive juice filling the latter, the first blood. All the lower animals with which we have yet occupied ourselves in our Phylogeny, all the Primitive Animals and Plant-animals, are, like the Accœlomi, bloodless and without a body-cavity. In the formation of a special vascular system, the earliest Cœlomati made a very great advance. Much of the complexity in the organic structure in the four higher tribes of animals is based on the differentiation of the vascular system, which they have inherited from the Blood-bearing Worms.

The first development of a true body-cavity (*cœloma*) is referable to the separation of the two fibrous layers; to the formation of a spacious cavity between the outer skin-fibrous layer and the inner intestinal-fibrous layer. In the fissure-like gaps, which formed between the two germ-layers, a juice collected, which penetrated through the intestinal wall. This juice was the first blood, and the gaps between the two germ-layers formed the first rudiment of the body-cavity. The union of these gaps formed the simple cœlom, the large cavity, containing blood or lymph, which plays so important a part in all the higher animals as the receptacle of the very extensive intestines. The formation of this cœlom, and of the blood-vessels developed in connection with it, exercised a very great influence on the further evolution of the animal organization. The most important result was, that it allowed the conveyance of rich nutritive juices to those parts of the body lying near the circumference, and developing at a considerable distance from the intestinal canal. The intimate correlation, or reciprocity of the parts, necessarily occasioned, in direct connection with the progressive development of the blood-vessel system, many other important advances in the structure of the body of the Blood-bearing Worms.

Just as among the Accœlomi, so also among the Cœlomati, the pedigree of our race must have passed through a large number of diverse ancestral stages. But among extant Cœlomati (which form but a very small fraction of this once multiform group), there are but very few Worms which can with certainty be regarded as nearly allied to the long-extinct ancestors of Man. In this respect, but a single class of Cœlomati is really of prominent importance; these are the Mantled Animals (*Tunicata*), to which belong the Ascidia already known to us. Our careful examination of the structure and germ-history of the Ascidian and the Amphioxus have shown the extreme importance of these very interesting animal forms. (Cf. Chapters XIII. and XIV.) That examination fully justifies us in asserting that among the ancestors of the Vertebrates (and therefore of Man) there was an unknown extinct cœlomate species, to which the nearest allied form among extant animals is the Appendicularia (Fig. 187), of which we have already spoken, and the tailed Ascidian larva. We will for the present call this kind of Worm, which was primarily distinguished by the possession of a notochord, the Chorda-animal (*Chordonium*). The Ascidians on the one hand, and the Vertebrates on the other, developed, as two diverging branches, from these Chorda-animals. The common parent-form of the Chorda-animals themselves was a cœlomate form, which finally must have descended from the Acœlomi, and from the Archelminthes.

Many connecting intermediate forms must, of course, have existed between these two groups of Worms, between the Primitive Worms and the Chorda-animals. Unfortunately, however, zoological knowledge is at present especially imperfect with regard to these important intermediate forms of the multiform Worm tribe. For very evident reasons, none of these Worms could leave fossil remains. For, like the great majority of other Worms, they had no hard parts in their bodies. Most even of the known fossil Worms are worthless, for they tell us little or nothing of the most important structural features of the soft body. Fortunately, however, we can in great measure satisfactorily fill the considerable palæontological gap in this part of our pedigree, with the help of the Comparative Anatomy and Ontogeny of Worms. If, on the one hand, we examine the structure and mode of development of the lower Worms from the Gliding-Worms (*Turbellaria*), and, on the other hand, the Anatomy and Ontogeny of the Ascidians, it is not difficult, step by step, to re-construct in imagination the connecting intermediate forms, and to insert a series of extinct ancestral forms between the Acœlomi and the Chordonia. This series of forms under the name of Soft-worms (*Scolecida*) we will consider as the seventh stage in the human pedigree.

An examination of the Comparative Anatomy of the various Scolecid forms, which we might perhaps distinguish here, would lead us much too far into the difficult details of the Comparative Anatomy and Ontogeny of the Worms. For our purpose it seems more important to call attention to those phylogenetic advances, by means of which the organization of the earliest Blood-bearing Worms was in the end elevated to that of the Chorda-animals. The Comparative Anatomy and Ontogeny of the Gliding-worms and of the Ascidians justify us in giving special weight to the significant differentiation of the intestinal canal into two distinct divisions; into an anterior division (the gill-intestine), which accomplishes respiration, and a posterior division (the stomach-intestine), which accomplishes digestion. As in Gastræads and Primitive Worms, so also in the Ascidian larva, the intestinal canal is at first a simple pouch-like body, provided merely with a mouth-opening. A second opening, the anus, does not develop till a later period. Gill-openings afterwards appear in the anterior section of the intestinal canal, by which the whole anterior intestine is transformed into a gill-body. This remarkable arrangement is, as we found, quite peculiar to Vertebrates, and, except in the Ascidians, occurs nowhere else. Among extant Worms there is, however, a single isolated and very remarkable Worm form, which in this respect may be regarded as distantly allied to the Ascidia and to Vertebrates, and perhaps as an off-shoot from the Soft-worms (*Scolecida*). This is the so-called "Acorn-worm" (*Balanoglossus*, Fig. 186), which lives in the sand of the sea-shore. The interesting points connecting this with Ascidians and the Skull-less Animals (*Acrania*) were first accurately observed and explained by Gegenbaur. Although this singular Balanoglossus is in many other respects peculiar in its organization, so that Gegenbaur rightly ranked it as the representative of a special class (*Enteropneusta*), yet the structure of the anterior section of the intestinal tube is exactly similar to that of Ascidians and Skull-less Animals (*k*), a gill body, the walls of which are pierced on either side by gill-openings and are supported by gill-arches. Now, although the Acorn-worm in other points of its structure may differ very considerably from those extinct Soft-worms (*Scolecidæ*), which we must regard as direct ancestors of our race, and as intermediate links between the Primitive Worms

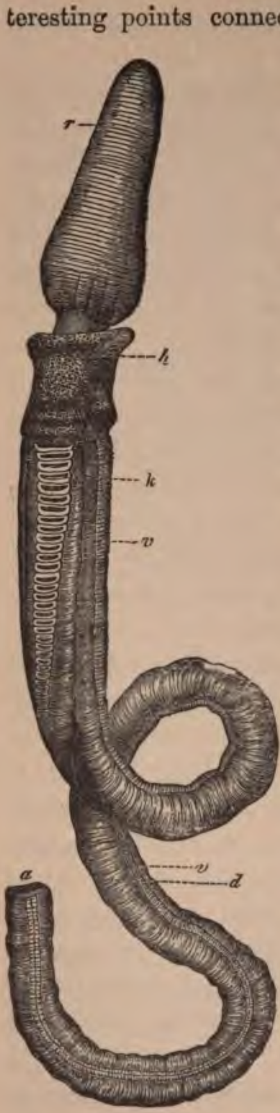


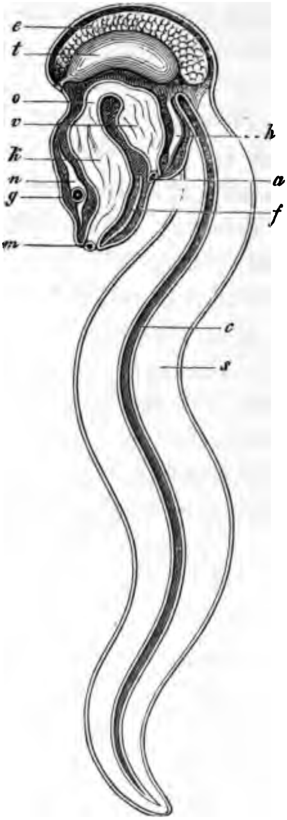
FIG. 186.—A young Acorn-worm (*Balanoglossus*). (After Alexander Agassiz.) *r*, acorn-like proboscis; *h*, collar; *k*, gill openings and gill-arches of the anterior intestine, in a long row one behind another on each side; *d*, digestive posterior intestine, filling the greater part of the body-cavity; *v*, intestinal vessel, lying between two parallel folds of skin; *a*, anus.

and the Chorda-animals, yet, in virtue of this characteristic structure of the gill-intestine, it may be considered a remotely allied collateral line of the Soft-worms. The development of an anus (Fig. 186, *a*) at the end opposite to the mouth, is also a considerable advance in the structure of the intestine. The further development of the blood-vessel system in the Acorn-worm also indicates a marked advance. In the ciliary surface of the skin, on the contrary, it recalls the Gliding-worms. The sexes are separated, while our scolecid ancestors were probably hermaphrodite.[145]

From a branch of the Soft-worms, the group of Chorda-animals (*Chordonia*), the common parent-group of the Mantle-animals and Vertebrates also developed. The process which primarily led to the development of this important group of the cœlomati, was the formation of the inner axial skeleton (the notochord, or *chorda dorsalis*), which at the present day we find permanently retained in its simplest form in the lowest Vertebrate, the Amphioxus. We saw that this notochord is already found in the tailed and free-swimming larva of the Ascidian (Plate X. Fig. 5). The chorda does, indeed, serve specially as a support for the rudder-like tail of the larval Ascidian, but its anterior extremity passes in between the intestinal and medullary tubes within the actual body of the larva. A transverse section of this larva therefore shows that arrangement of the most important organs which is characteristic of the vertebrate type: in the centre is the firm notochord, which supports the other organs and serves especially as a base and point of attachment for the motive trunk muscles; above this notochord, on the dorsal side, is the central nervous system in the form of a medullary tube; below, on the ventral side, is the intestinal tube, the anterior half of which is a respiratory gill-intestine, its posterior half a digestive stomach-intestine. It is true that the free-swimming larva of the extant Ascidian possesses this typical vertebrate character only for a short time; it soon relinquishes its free roving mode of life, puts off its oar-like tail with the notochord, adheres to the bottom of the sea, and then undergoes that very great retrogression, the surprising final result of which we have already observed (Chapters XIII. and XIV.). Nevertheless, the Ascidian larva, in its very transitory evolution (for a brief space), affords us a picture of the long extinct Chordona-form, which must be regarded as the common parent-form of Mantle-animals and Vertebrates. There is even yet extant a small and insignificant form of Mantle-animal which throughout life retains the structure of the Ascidian larva with its oar-like tail and its free-swimming mode of life, and which reproduces itself in this form. This is the remarkable Appendicularia (Fig. 187), which we have already examined.

If we ask ourselves what conditions of adaptation could possibly have had so remarkable a result as the development of the notochord, and the modification of a branch of the Soft-worms into the parent-form of the Chorda-animals, we may with great probability answer, that this result was effected by the habituation of the creeping Soft-worm to a swimming mode of life. By energetic and continued swimming movements, the muscles of the trunk would be greatly developed, and a strong internal point of attachment would be very favourable to this muscular activity. A support of this kind might arise by enlargement and concrescence of the germ-layers along the longitudinal axis of the body; and the differentiation of an independent bony cord from this axial cord gave rise to the notochord. (Cf. Fig. 88, 89, vol. i. pp. 300, 301.) In correlation to the formation of this central notochord, the simple nerve-ganglia, lying over the throat in the Soft-worms, lengthened into a long nerve-cord, reaching from front to rear, above the notochord; in this way, the medullary tube originated from the "upper throat ganglia."

As we have already minutely considered the great significance of the Ascidians (Fig. 188) in this respect, as well as their close relations to the Amphioxus (Fig. 189), we will not tarry longer over this point now. I will repeat, that we must by no means regard the Ascidian as the direct parent-form of the Amphioxus and of the other Vertebrates. On the contrary, we assert that, on the one hand the Ascidians, and on the other the Vertebrates, have both descended from one unknown Worm form, which has long been extinct; the nearest relatives of this among existing animals are the Ascidian larvæ and the Appendicularia (Fig. 187). This unknown common parent-form must have belonged to the group of Chorda-animals, which we pointed out as the eighth ancestral stage in the human pedigree.[146] Although we cannot form an entirely satisfactory idea as to all points of external and internal structure of this Chorda-animal, there is no doubt that, like its near relatives, the Mantle-animals, and like the preceding ancestral stage represented by the Soft-worms and Primitive Worms, it must be classified in the natural system of the animal kingdom as a genuine Worm. The difference between it and other genuine Worms cannot have been greater than is



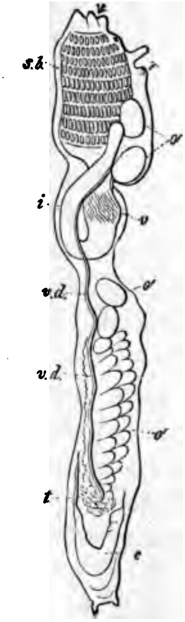


FIG. 187.—Appendicularia, seen from the left side: *m*, mouth; *k*, gill-intestine; *o*, œsophagus; *v*, stomach; *a*, anus; *n*, nerve-ganglia (upper throat-knots); *g*, ear-vesicle; *f*, ciliated groove under the gill; *h*, heart; *t*, testes; *e*, ovary; *c*, notochord; *s*, tail.

FIG. 188.—Structure of an Ascidian (seen from the left, as in Fig. 153 and Fig. 14, Plate XI.): *sb*, gill-sac; *v*, stomach; *i*, large intestine; *c*, heart; *t*, testes; *vd*, seed-duct; *o*, ovary; *o'*, matured eggs in the body-cavity. (After Milne Edwards.)

the difference between the extant Tape-worms and Ringed Worms (*Annelida*). Moreover, in a certain sense we may regard the extant Appendicularia as a last remnant of the Chordonia class.

We have now studied the most important animal forms which occur in the pedigree of the human race, and which, in the zoological system, must be classed among the Worms. In leaving this lower class, and tracing our ancestry henceforth exclusively within the vertebrate tribe, we at once leave behind the great majority of animal forms, which branched off from the worm tribe in entirely different directions. When, in a previous chapter (IX.), the vertebrate nature of man was proved, it was incidentally mentioned that the very great majority of animals are in no way directly allied to our tribe. The parent-forms of the three other higher Animal tribes, the Articulated Animals (*Arthropoda*), Star-animals (*Echinoderma*), and Soft-bodied Animals (*Mollusca*), like the vertebrate tribe, originated from the

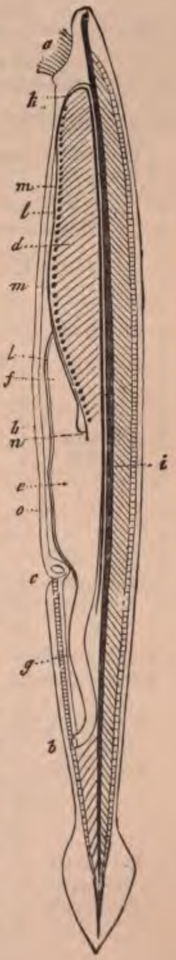


FIG. 189.—Lancelet (*Amphioxus lanceolatus*), twice the actual size, seen from the left (the longitudinal axis is represented vertically, the mouth turned upward, the tail downward, as in Plate XI. Fig. 15): *a*, mouth-opening, surrounded by cilia; *b*, anal opening; *c*, ventral opening (*Porus abdominalis*); *d*, gill-body; *e*, stomach; *f*, liver-cœcum; *g*, large intestine; *h*, cœlom: *i*, notochord (under it the aorta); *k*, arches of the aorta; *l*, main gill-artery; *m*, swellings on its branches; *n*, hollow vein; *o*, intestinal vein.

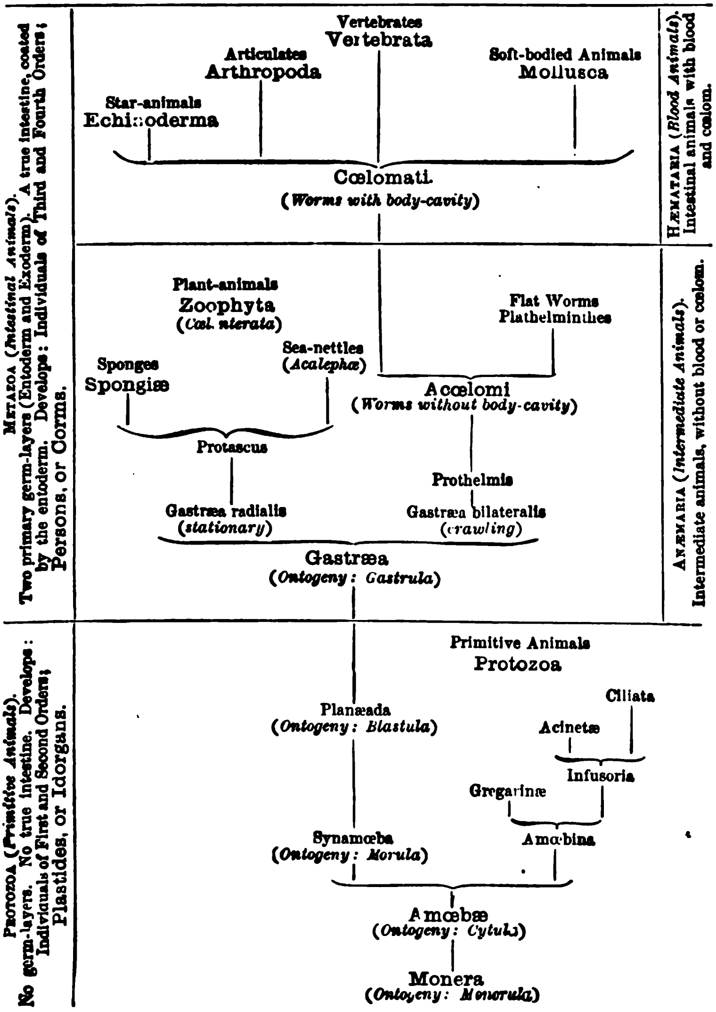
TABLE XVIII.

Systematic Survey of the Phylogenetic System of the Animal Kingdom, founded on the Gastræa Theory and the Homology of the Germ-layers.

Tribes or Phyla of the Animal Kingdom.	*Main Classes or Branches of the Animal Kingdom.*	*Classes of the Animal Kingdom.*	*Systematic Names of the Classes.*
FIRST SUB-KINGDOM: PRIMITIVE ANIMALS (*Protozoa*). Animals without germ-layers, intestine, or true tissues.			
A. Primitive Animals **Protozoa**	I. Egg-animals *Ovularia*	1. Monera	1. Monera
		2. Amœbæ	2. Lobosa
		3. Gregarinæ	3. Gregarinæ
	II. Infusorial animals *Infusoria*	4. Sucking Infusoria	4. Acinetæ
		5. Ciliated Infusoria	5. Ciliata
SECOND SUB-KINGDOM: INTESTINAL ANIMALS (*Metazoa*). Animals with two primary germ-layers, intestines and tissues.			
B. Plant-Animals **Zoophytes**	III. Sponges *Spongiæ*	6. Primitive intestinal animals	6. Gastræada
		7. Sponges	7. Porifera
	IV. Sea-nettles *Acalephæ*	8. Corals	8. Coralla
		9. Hood-jellies	9. Hydromedusæ
		10. Comb-jellies	10. Ctenophora
C. Worms **Vermes**	V. Bloodless worms *Acœloma*	11. Primitive worms	11. Archelminthes
		12. Flat-worms	12. Plathelminthes
	VI. Blood-worms *Cœlomati*	13. Round-worms	13. Nemathelminthes
		14. Arrow-worms	14. Chœtognathi
		15. Wheel-animalcules	15. Rotatoria
		16. Moss-polyps	16. Bryozoa
		17. Mantle-animals	17. Tunicata
		18. Acorn-worms	18. Enteropneusta
		19. Star-worms	19. Gephyrea
		20. Ringed-worms	20. Annelida
D. Soft-bodied Animals **Mollusca**	VII. Headless shell-fish *Acephala*	21. Lamp-shells	21. Spirobranchia
		22. Mussels	22. Lamellibranchia
	VIII. Head-bearing shell-fish *Eucephala*	23. Snails	23. Cochlides
		24. Cuttles	24. Cephalopoda
E. Star-Animals **Echinoderma**	IX. Ringed-arms *Colobrachia*	25. Sea-stars	25. Asterida
		26. Sea-lilies	26. Crinoida
	X. Armless *Lipobrachia*	27. Sea-urchins	27. Echinida
		28. Sea-cucumbers	28. Holothuriæ
F. Articulated Animals **Arthropoda**	XI. Gill-breathers *Carides*	29. Crabs	29. Crustacea
	XII. Tube-breathers *Tracheata*	30. Spiders	30. Arachnida
		31. Centipedes	31. Myriopoda
		32. Flies	32. Insecta
G. Vertebrate Animals **Vertebrata**	XIII. Skull-less *Acrania*	33. Tube-hearts (Lancelets)	33. Leptocardia
	XIV. Single-nostrilled *Monorrhina*	34. Round-mouths (Lampreys)	34. Cyclostoma
	XV. Amnion-less *Anamnia*	35. Fishes	35. Pisces
		36. Mud-fish	36. Dipneusta
		37. Amphibians	37. Amphibia
	XVI. Amnion-animals *Amniota*	38. Reptiles	38. Reptilia
		39. Birds	39. Aves
		40. Mammals	40. Mammalia

TABLE XIX.

Monophyletic Pedigree of the Animal Kingdom, founded on the Gastræa Theory and the Homology of the Germ-layers.[24]



worm tribe; but the parent-forms of the three former belong to worm-groups quite distinct from that of the Chordonia. It is only far down at the common root of the group of Cœlomati, that we assume a common source for these various tribal forms. (Cf. Tables XVIII. and XIX.) It is especially necessary to remember that there is no direct blood-relationship between Vertebrates and Articulated Animals.

The Articulated Animals (*Arthropoda*), to which the most comprehensive of all classes of animals, that of Insects, and also the Spiders, Centipedes, as well as the Crabs, or Crustaceans, belong, are descendants of articulated Worms, the nearest allies of which are the extant Ringed Worms (*Annelida*). The tribe of Star-animals (*Echinoderma*), which includes the Star-fishes, Sea-lilies, Sea-urchins, and Sea-cucumbers, must also have descended from similar articulated Worms.[118] The parent-form of the Soft-bodied Animals (*Mollusca*), which include the Cuttles, Snails, Mussels, and Lamp-shells, must also be sought among the Worms. But the Cœlomati, from which these three higher animal tribes originated, differed entirely in character from the Chorda-animals. Unlike the latter, they never developed a notochord. In them, the anterior section of the intestinal tube was never modified into a gill-body with gill-openings; nor were the upper throat-ganglia developed into a medullary tube. In a word, in Articulated Animals, Star-animals, and Soft-bodied Animals, as well as in their ancestors among the Blood-bearing Worms, the typical structural peculiarities which are exclusively characteristic of the vertebrate tribe and of their immediate invertebrate progenitors, were never present. Thus the great majority of all animals are in no way the subject of our further investigations, which are only concerned with the Vertebrates.

The development of the Vertebrates from the Invertebrates most nearly related to them, the Chorda-Animals, occurred millions of years ago, during the Archilithic Epoch. (See Table XII., p. 11.) This is unmistakably shown by the fact that the most recent sedimentary rock-strata which were deposited during that immense period of time, the higher layers of the Upper Silurian formation, contain remains of fossil Fishes (Primitive Fishes, *Selachii*). As these Fishes, although they belong to the lowest stage of the Skulled Animals (*Craniota*), yet possess a comparatively high organization, and as they must necessarily have been preceded by a long progressive series of lower Skull-less Vertebrates, we must attribute the origin of the oldest Skull-less Animals (*Acrania*) from the Chorda-animals to a much earlier part of the Archilithic Epoch. Therefore, not only all the invertebrate ancestors of our race, but also the earliest form of our vertebrate progenitors must have developed in that primordial time, which includes the Laurentian, Cambrian, and Silurian Periods. (Cf. Tables XIII., XIV., and XVI., pp. 12, 19, 44.)

Unfortunately, Palæontology can give us absolutely no information with regard either to the structure of our oldest vertebrate ancestors, or to the time of their appearance; for their bodies were as soft and as destitute of hard parts capable of fossilization, as were the bodies of all our preceding invertebrate ancestors. It is, therefore, not surprising, but quite natural, that we find no fossil remains of the former in the Archilithic formations. The Fishes in which the soft cartilaginous skeleton was partly modified into hard bone, are the earliest Vertebrates capable of leaving petrified records of their existence and structure.

Fortunately, this want is more than counterbalanced by the much more important testimony of Comparative Anatomy and Ontogeny, which henceforth form our safest guides within the Vertebrate pedigree. Thanks to the classic researches of Cuvier, Johannes Müller, Huxley, and especially of Gegenbaur, we are in possession of such extensive and instructive records of creation in this most important branch of tribal history, that we can prove at least the more significant features in the development of our Vertebrate ancestors, with the most gratifying certainty.

The characteristic peculiarities by which Vertebrates in general are distinguished from all Invertebrates, engaged our attention some time ago, when we examined the structure of the ideal Primitive Vertebrate (Figs. 52–56, p. 256). The most prominent characters were as follows: (1) the formation of the notochord between the medullary and intestinal tubes; (2) the differentiation of the intestinal tube into an anterior gill-intestine and a posterior stomach-intestine; (3) the inner articulation, or formation of metamera. The Vertebrates share the first two qualities with the larval Ascidians and with the Chorda-animals; the third quality is entirely peculiar to them. Accordingly, the most important structural advance, by which the earliest vertebrate forms originated from the most nearly allied Chorda-Animals, consisted in an internal metameric structure. This showed itself first most distinctly in the articulation of the muscular system, which broke up on the right and left into a series of consecutive muscular plates. At a later period the articulation declared itself prominently in the skeleton, and nervous and blood-vessel systems. As we have already seen, this process of articulation, or metameric formation, must essentially be regarded as terminal germination. Each distinct trunk-segment, or metameron, represents an individual. Thus the Vertebrates with their internal segmentation stand in a similar relation to their inarticulate Invertebrate ancestors, the Chorda Animals, as do the outwardly segmented Ringed Worms (*Annelida*) and Articulated Animals (*Arthropoda*) to the simple inarticulate Worms from which they originated.

The tribal history of Vertebrates is rendered much more intelligible by the natural classification of the tribe which I proposed first in my *Generelle Morphologie* (1866), and afterwards improved in many ways in "The Natural History of Creation" (Chap. XX., p. 192, etc.). In accordance with that, existing Vertebrates must be divided into at least eight classes, as follows:—

SYSTEMATIC SURVEY OF THE EIGHT CLASSES OF VERTEBRATES.

A. Skull-less (*Acrania*)			**1. Tube-hearted**	1. Leptocardia
B. Skulled *Craniota*	**a. Single-nostrilled (*Monorhina*)**		2. Round-mouths	**2. Cyclostoma**
	b. Double-nostrilled *Amphirhina*	I. Amnion-less *Anamnia*	3. Fishes	3. Pisces
			4. Mud-fishes	4. Dipneusta
			5. Amphibians	5. Amphibia
		II. With Amnion *Amniota*	6. Reptiles	6. Reptilia
			7. Birds	7. Aves
			8. Mammals	8. Mammalia

The whole Vertebrate tribe may primarily be divided into the two main sections of the Skull-less and the Skulled Vertebrates. Of the earlier and lower section, that of the Skull-less (*Acrania*), the Amphioxus is alone extant. To the more recent and higher section, the Skulled (*Craniota*), belong all other existing Vertebrates up to Man. The

Craniota branched off from the Acrania, as these did from the Chorda Animals. Our exhaustive study of the Comparative Anatomy and Ontogeny of the Ascidian and the Amphioxus have already afforded proof of this relation. (Cf. Chapters XIII. and XIV., and Plates X. and XI. with the explanations.) I will only repeat, as the most important fact, that the Amphioxus develops from the egg in exactly the same way as the Ascidian. In both, the original Bell-gastrula (Figs. 4 and 10) originates in an exactly similar manner, by primordial cleavage from the simple parent-cell (Figs. 1 and 7). From this originates that remarkable larva, which develops a medullary tube on the dorsal side of the intestinal tube, and between the two a notochord. At a later period, both in the Ascidian and in the Amphioxus, the intestinal tube differentiates into an anterior gill-intestine and a posterior stomach-intestine. In accordance with the fundamental principle of Biogeny, from these very important facts we may deduce the following statement of great phylogenetic importance: the Amphioxus, the lowest Vertebrate form, and the Ascidian, the most nearly allied Invertebrate form, have both descended from one single extinct Worm form, which must have possessed the essential structure of the Chorda Animals.

The Amphioxus, as has already been often shown, is of extreme importance; not only because it thus fills the great gap between the Invertebrates and the Vertebrates, but also because it represents, at the present time, the typical Vertebrate in its simplest form; and because it directly affords the best standpoint from which to examine the gradual historic evolution of the whole tribe. If the structure and germ-history of the Amphioxus were unknown to us, the whole subject of the development of the Vertebrate tribe, and thus of our own race, would be enveloped in an impenetrable veil. The accurate anatomical and ontogenetic knowledge of the Amphioxus, attained during the last few years, has alone pierced that heavy veil, formerly supposed to be impenetrable. If the Amphioxus is compared with the developed Man or any other of the higher Vertebrates, a great number of striking dissimilarities will be seen. The Amphioxus has no specialized head, no brain, no skull, no jaws, no limbs; it is without a centralized heart, a developed liver and kidneys, a jointed vertebral column; every organ appears in a much simpler and more primitive form than in the higher Vertebrates and in Man. (Cf. Table X., vol. i. p. 466.) And yet, in spite of all these various deviations from the structure of other Vertebrates, the Amphioxus is a genuine, unmistakable Vertebrate; and if, instead of the developed Man, the human embryo at an early period of its Ontogeny is compared with the Amphioxus, we shall find perfect parallelism between the two in all essential points. (Cf. Table IX., vol. i. p. 465.) This highly important parallelism justifies the conclusion that all the Skulled Animals (*Craniota*) have descended from a common primæval parent-form, the structure of which was essentially that of the Amphioxus. This parent-form, the earliest Primitive Vertebrate, possessed the peculiar characters of the Vertebrates, and yet was without all those important peculiarities that distinguish the Skulled Animals from the Skull-less. Although the Amphioxus appears peculiarly organized in many respects, and although it may not be regarded as an unmodified descendant of the Primitive Vertebrate, yet it must have inherited from the latter the distinguishing characteristic features already mentioned. We cannot therefore say that the Amphioxus is the progenitor of the Vertebrates; but we may certainly say that the Amphioxus of all known animals is nearest allied to this progenitor; both belong to the same limited family group, to the lowest Vertebrate class, that of the Skull-less Animals (*Acrania*). In the human pedigree, this group forms the ninth stage of the ancestral chain, the first among Vertebrate ancestors. From this Skull-less group was developed the Amphioxus on the one side, and on the other the parent-form of the Skulled Animals (*Craniota*).

The comprehensive group of the Skulled Animals includes all known Vertebrates, with the single exception of the Amphioxus. All these Skulled Animals possess a distinct head, inwardly specialized from the trunk, and this contains a skull, enclosing a brain. This head also carries three of the higher sense-organs, which are partially wanting in the Skull-less Animals (nose, ears, and eyes). At first, the brain appears in a very simple form, as an anterior bladder-like extension of the medullary tube (Plate XI. Fig. 16, m_1). This, however, is soon distributed by several tranverse grooves—first into three, and afterwards into a series of five consecutive brain-bladders. In the formation of the head, skull, and brain, together with the higher sense-organs, lies the most essential advance made by the skulled parent-form beyond its skull-less ancestors. Other organs, however, also soon rose to a higher grade of development; a compact centralized heart appeared, a more perfect liver and kidneys; and in other directions also important advance was made.

The Skull-less Animals may be primarily subdivided into two differing main sections, that of the Single-nostrils (*Monorhina*), and that of the Double-nostrils (*Amphirhina*). Of the former there are but very few extant forms, which are called Round-mouths (*Cyclostoma*). These are, however, of great interest, because in their whole structure they are intermediate between the Skull-less Animals and the Double-nostrils (*Amphirhina*). Their organization is much higher than that of the Skull-less Animals, much lower than that of the Double-nostrils; they thus form a very welcome phylogenetic link between those two divisions. We may therefore represent them as a special, tenth stage in the human ancestral series.

The few existing species of the class of Round-mouths are distributed into two different orders, which are distinguished as the Hags and the Lampreys. The Hags (*Myxinoides*) have long, cylindrical, worm-like bodies. Linnæus classed them among Worms, but later zoologists have placed them, sometimes among the Fishes, sometimes Amphibians, and again with Molluscs. The Hags live in the sea and are usually parasitic on Fishes, into the skin of which they penetrate by means of their round sucking mouths and their toothed tongues. They are occasionally found in the body-cavity of Fishes—for example, of the Cod and Sturgeon—having penetrated to the interior in their passage through the skin. The second order, that of the Lampreys (*Petromyzontes*), includes those well-known "Nine eyes," common at the seaside; the little river Lamprey (*Petromyzon fluviatilis*) and the large sea Lamprey (*Petromyzon marinus*, Fig. 190).

The animals included in the two groups of the *Myxinoides* and the *Petromyzontes*, are called Round-mouths

(*Cyclostoma*), from the fact that their mouth forms a circular or semi-circular opening. The upper and under jaws, which appear in all the higher Vertebrates, are completely wanting in the Round-mouths, as in the Amphioxus. All other Vertebrates are therefore distinguishable from them as "Jaw-mouthed" (*Gnathostomi*). The Round-mouths may also be called "Single-nostrils" (*Monorhina*), because they have but a single nasal tube, while the Gnathostomi are all furnished with a pair of nasal cavities, a right and a left nose-cavity ("Double-nostrilled," *Amphirhina*). But in addition to these peculiarities, the Jaw-mouths are also distinguished by many other remarkable structural arrangements, and are further removed from the Fishes than the latter are from Man. They must, therefore, evidently be regarded as the last remnant of a very old and very low class of Vertebrates, which are far below the structural stage of a genuine Fish. To mention here briefly only the most important, the Round-mouths are entirely without any trace of limbs. Their slimy skin is quite naked and smooth, without scales. They are wholly destitute of a bony skeleton. The inner skeleton axis is a very simple inarticulate notochord, like that of the Amphioxus. In the Lampreys alone a rudimentary articulation is indicated by the fact that upper arches appear in the vertebral tube proceeding from the notochord sheath. At the anterior end of the chorda a skull is developed in its very simplest form. From the notochord sheath proceeds a small soft-membraneous skull capsule, which becomes partly cartilaginous: this capsule encloses the brain. The important apparatus of the gill-arches, the tongue-bone, etc., which is inherited by all Vertebrates from Fishes to Man, is wholly wanting in the Round-mouths. They have, indeed, a superficial, cartilaginous gill-skeleton, but this is of quite different morphological significance. On the other hand, in them we meet, for the first time, with a brain, that important mental organ, which has been transmitted from the Single-nostrils up to Man. It is true that in the Round-mouths the brain appears merely as a very small and comparatively insignificant swelling of the spinal chord; at first a simple bladder (Plate XI. Fig. 16, m_1), which afterwards separates into five consecutive brain-bladders, as in the brains of all Double-breathers. These five simple primitive brain-bladders, which reappear in a similar form in the embryos of all higher Vertebrates, from Fishes up to Man, and which undergo a very complex modification, remain in the Round-mouths, in a very low and undifferentiated stage of development. The histological elementary structure of the nervous system is also much more imperfect than in other Vertebrates. While in the latter the organ of hearing always has three semi-circular canals, in the Lampreys it has but two, and in the Hags but one. In most other points also, the organization of the Round-mouths is

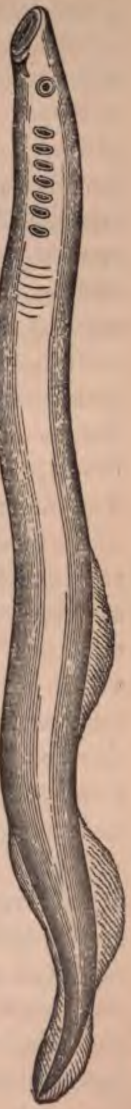


FIG. 190.—The large Sea-lamprey (*Petromyzon marinus*), much reduced in size. A series of seven gill-openings are visible below the eye.

much simpler and more imperfect, as, for instance, in the structure of the heart, the circulatory system, and the kidneys. In them, as in the Amphioxus, the anterior portion of the intestinal canal does, indeed, form respiratory gills; but these respiratory organs are developed in a very peculiar way: in the form of six or seven little pouches, or sacs, which lie on both sides of the anterior intestine and communicate with the throat (*pharynx*) by inner openings, and by outer ones with the external skin. This is a very peculiar formation of the respiratory organs, quite characteristic of this class of animals. They have therefore been called the "Pouch-gills" (*Marsupobranchii*). The absence of one very important organ found in the Fishes, the swimming-bladder, from which the lungs of the higher Vertebrates have developed, should be especially noticed.

In their germ-history, as in their whole anatomical structure, the Round-mouths present many peculiarities. They are even peculiar in the unequal cleavage of the egg, which most nearly approaches that of the Amphibians (Fig. 31, vol. i. p. 203). This results in the formation of a Hood-gastrula, like that of Amphibians (Plate II. Fig. 11). From this develops a very simple organized larval form, which is closely allied to the Amphioxus, and which, for that reason, we examined and compared with the latter (vol. i. p. 428, and Plate VIII. Fig. 16). The gradual germ-evolution of these larvæ of the Round-mouths explains very clearly and unmistakably the gradual evolution of the Skulled from the Skull-less class of Vertebrates. At a later period, from this simple Lamprey larva is developed a blind and toothless larval form, which is so very different from the mature Lamprey that, until twenty years ago, it was generally described as a peculiar form of fish under the name of *Ammocœtes*. By a further metamorphosis this blind and toothless Ammocœtes is transformed into the Lamprey with eyes and teeth (*Petromyzon*).[147]

Summing up all these peculiarities in the structure and embryology of the Round-mouths, we may assert that the oldest Skulled Animals, or *Craniota*, diverged in two lines; one of these lines has continued up to the present time but little modified; it is represented by the Cyclostoma, or Monorhina, forming a collateral line which has made but little progress, but has remained at a very low stage of development. The other line, the direct line in the pedigree of the Vertebrates, advanced in a straight line to the Fishes, and by new adaptations attained many important improvements.

In order rightly to appreciate the phylogenetic significance of interesting remnants of primæval groups of animals, such as the Round-mouths, it is necessary to study minutely their various peculiar characters philosophically and with the aid of Comparative Anatomy. A careful distinction must be drawn between the hereditary characters which have been accurately transmitted to the present day by heredity from common, primæval ancestors, now extinct, on the one hand; and, on the other, those special adaptive peculiarities which the existing remnant of that primæval group have, in the course of time, gained secondarily by adaptation. To the latter class belong, for example, in the Round-mouths, the peculiar formation of the single nostril and the round sucking mouth; as well as special structural arrangements of the epidermis and the pouch-shaped gills. But, on the other hand, to the former class of characteristics, which alone have any phylogenetic significance, belong the primitive formation of the vertebral column and the brain, the absence of the swimming-bladder, of jaws, limbs, etc.

In the animal system, the Round-mouths are usually classed among Fishes; but that this is quite incorrect is apparent from the simple fact that, in all important and prominent structural peculiarities, they are further removed from the Fishes than the Fishes are from the Mammals and from Man.

CHAPTER XVIII.

THE PEDIGREE OF MAN.

III. FROM THE PRIMITIVE FISH TO THE AMNIOTIC ANIMAL.

Comparative Anatomy of the Vertebrates.—The Characteristic Qualities of the Double-nostrilled and Jaw-mouthed: the Double-Nostrils, the Gill-arch Apparatus, with the Jaw-arches, the Swimming-bladder, the Two Pairs of Limbs.—Relationship of the Three Groups of Fishes: the Primitive Fishes (*Selachii*), the Ganoids (*Ganoides*), the Osseous Fishes (*Teleostei*).—Dawn of Terrestial Life on the Earth.—Modification of the Swimming-bladder into the Lungs.—Intermediate Position of the Dipneusta between the Primitive Fishes and Amphibia.—The Three Extant Dipneusta (*Protopterus, Lepidosiren, Ceratodus*) —Modification of the Many-toed Fin of the Fish into the Five-toed Foot.—Causes and Effects of the latter.—Descent of all Higher Vertebrates from a Five-toed Amphibian.—Intermediate Position of the Amphibians between the Lower and Higher Vertebrates.—Modification or Metamorphosis of Frogs.—Different Stages in Amphibian Metamorphosis.—The Gilled Batrachians (*Proteus* and *Axolotl*).—The Tailed Batrachians (Salamanders and Mud-fish).—Frog Batrachians (Frogs and Toads).—Chief Group of the Amnion Animals, or *Amniota* (Reptiles, Birds, and Mammals).—Descent of all the Amniota from a Common Lizard-like Parent-form (*Protamnion*).—First Formation of the Allantois and of the Amnion.—Branching of the Amnion Animals in Two Lines: on the one side, Reptiles (and Birds), on the other side, Mammals.

"The imagination is an indispensable faculty; for it is that which, by forming new combinations, occasions important discoveries. The naturalist needs both the discriminating power of abstract reason, and the generalizing power of the imagination, and that the two should be harmoniously inter.

related. If the proper balance of these faculties is destroyed, the naturalist is hurried into chimerical fancies by his imagination; while the same gift leads the gifted naturalist of sufficient strength of reason to the most important discoveries."—JOHANNES MÜLLER (1834).

THE further we proceed in human tribal history, the narrower does that part of the animal kingdom become within which we must look for extinct ancestors of the human race. At the same time, the evidence as to the history of the evolution of our race given by what we have called the records of creation, the evidence of Ontogeny, of Comparative Anatomy, and of Palæontology, grows constantly more extensive, complete, and trustworthy. It is therefore natural that Phylogeny should assume a more definite form the nearer we approach the higher and the highest stages of the animal kingdom.

Comparative Anatomy especially has done far more for our knowledge of these higher stages of evolution in the animal kingdom than for the lower. This important science, which aims at a true philosophy of organic forms, has made greater progress in the Vertebrate tribe than in any section of the Invertebrate. Cuvier, Meckel, and Johannes Müller had already laid a deep and extensive foundation; and now the Comparative Anatomy of Vertebrates has recently been powerfully advanced by the admirable investigations of Owen and Huxley, and, especially, has been perfected to such a degree by the unsurpassed labours of Gegenbaur, that it now forms one of the strongest supports of the Theory of Descent. Relying on the evidence thus furnished, we can now, with a great degree of certainty, recognize the most important outlines of the series of stages and the ramifications of the Vertebrate pedigree.

That part of the animal kingdom with which we are now concerned has become so narrow, even before we have left the Archilithic Epoch, that but a single one of the seven tribes of the animal kingdom forms the object of our study. Even within this tribe we have passed the lowest steps, and have risen above the Skull-less (*Acrania*) and Double-nostrilled Vertebrates (*Monorhina*), to the class of Fishes. The latter are the first of the great main division of Vertebrates distinguished by mouths with jaws and by double nostrils (*Amphirhina*, or *Gnathostoma*). From Fishes we start again, as from that class of Vertebrates which are indubitably shown by Comparative Anatomy and Ontogeny to be the ancestral class of all higher Vertebrates, all Amphirhina. Of course no existing Fish can be regarded as the direct parent-form of the higher Vertebrates. But it is equally certain that from a common extinct Fish-like parent-form we may trace all those Vertebrates from Fishes up to Man, which are included under the name of Amphirhina. If this primæval parent-form were extant, we should undoubtedly describe it as a genuine Fish and class it among Fishes. Fortunately, the Comparative Anatomy and Classification of the Fishes has been so far advanced (thanks to the labours of Johannes Müller and Gegenbaur) that we can very clearly distinguish these most important and interesting genealogical relations.

In order correctly to understand the human pedigree within the Vertebrate tribe, it is very important to bear in mind the distinguishing characteristics, separating Fishes and all the other Double-nostrils (*Amphirhina*) from Single-nostrilled and Skull-less Animals (*Monorhina* and *Acrania*). These very distinguishing characteristic marks

Fishes have in common with all other Double-nostrils up to Man, and it is on this parallelism that we found our claim of relationship to Fishes. (Cf. Table X., vol. i. p. 466.) The following characters of the Double-nostrils must be especially indicated as the systematic anatomical features of the highest importance: (1) the double structure of the nose; (2) the internal gill-arch apparatus, together with the jaw-arches; (3) the swimming-bladder, or lungs; and (4) the two pairs of limbs.

As to the nasal structure, on which is based the distinction of the Single-nostrils (*Monorhina*) from the Double-nostrils (*Amphirhina*), it is certainly significant that even in Fishes the earliest rudiment of the nose consists of two entirely distinct lateral grooves or pits in the outer surface of the head, just as is the case in the embryo of Man and of all higher Vertebrates. On the other hand, in Single-nostrils and Skull-less Vertebrates the first rudiment of the nose is, from the first, a single pit in the centre of the forehead region. No less important is the higher development of the skeleton of the gill-arch and of the jaw apparatus connected with it, as it occurs in all Double-nostrils from Fishes to Man. It is true that the primitive modification of the anterior intestine into the gill-intestine, which occurs even in Ascidians, is developed in all Vertebrates from one simple rudiment; and in this respect the gill-openings, which in all Vertebrates and also in Ascidians pierce the wall of the gill-intestine, are quite characteristic. But the external framework of the gills, which in all Skull-less and Single-nostrilled Animals (*Acraniota* and *Monorhina*) supports the gill-body, is displaced in all Double-nostrils (*Amphirhina*) by an internal gill-skeleton which replaces the former

This internal gill-support consists of a consecutive series of cartilaginous arches, which are situated between the gill-openings within the wall of the throat (pharynx), and extend round the throat. The foremost of these pairs of gill-arches changes into the jaw-arch (maxillary arch), which gives rise to the upper and lower jaws.

A third essential character by which all Double-nostrils are well distinguished from all those lower Vertebrates which we have already considered, is the formation of a blind sac which protrudes from the anterior portion of the intestinal canal, and which in the Fishes becomes the air-filled swimming-bladder (Plate V. Fig. 13, *lu*). As this organ, in proportion as it contains a greater or less quantity of air, or in proportion as this air is more or less compressed, imparts a higher or lower specific gravity to the Fish, it acts as a hydrostatic apparatus. By this means the Fish can rise or sink in the water. This swimming-bladder is the organ from which the lung of higher Vertebrates has developed. The fourth and last main character of Double-nostrils is the presence of two pairs of extremities or members in the primitive arrangement of the embryo; a pair of fore limbs, which in Fishes are called pectoral fins (Fig. 191, *v*), and a pair of hind limbs, which in Fishes are called ventral fins (Fig. 191, *h*). The Comparative Anatomy of these fins is of supreme interest, because they contain the rudiments of all those parts of the skeleton which, in all the higher Vertebrates up to Man, form the skeleton or support of the extremities of the fore and hind limbs. In Skull-less and Single-nostrilled Animals there is, on the contrary, no trace of these extremities. In addition to these four most important main characters of the Amphirhina, we might further mention the presence of a sympathetic nerve-system, a spleen, a ventral salivary gland; organs which are not represented in the lower Vertebrates already considered. All these important parts have transmitted themselves from Fishes up to Man, and from this circumstance alone it is evident how wide a chasm separates the Fishes from the Skull-less and Single-nostrilled Animals (*Acraniota* and *Monorhina*). Fishes and Man possess all these characters in common (Table X.).

Turning now to consider the Fish class in greater detail, we may divide it primarily into three main groups, or sub-classes, the genealogies of which are evident. The first and most ancient group is that of the Primitive Fishes (*Selachii*), the best-known extant representatives of which are the members of the much-varied orders of Sharks and Rays (Figs. 191, 192). These are followed by a series of further developed Fish forms, by the sub-class of Mucous Fishes (*Ganoides*). The greater number of these have long been extinct, and only very few living representatives are known; these are the Sturgeon and Huso of European seas, the Polypterus of African, and the Lepidosteus and Amia of American rivers. The earlier abundance of forms belonging to this interesting group is, however, proved by the abundance of their fossil remains. From these Mucous Fishes originated the third sub-class, that of the Osseous Fishes (*Teleostei*), to which belong most extant Fishes, especially nearly all our river fish. Comparative Anatomy and Ontogeny very clearly show that the Ganoids sprang from the Selachii, just as the Teleostei sprang from the Ganoids. But, on the other hand, a second side-line, or rather the main ascending line of the Vertebrate tribe,

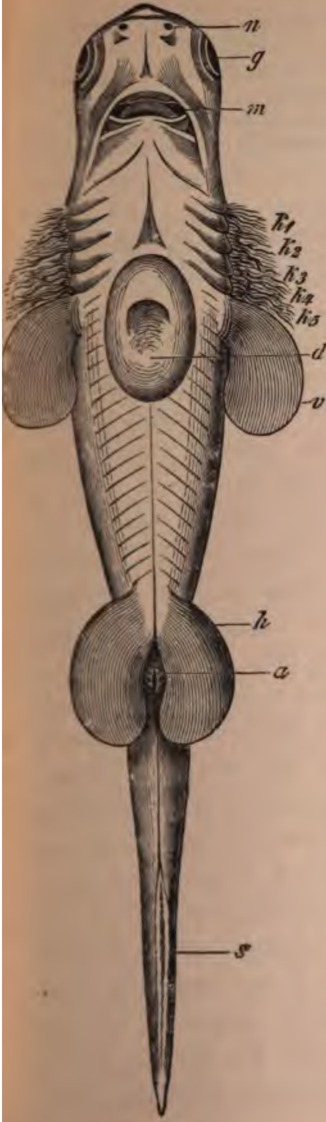


FIG. 191.

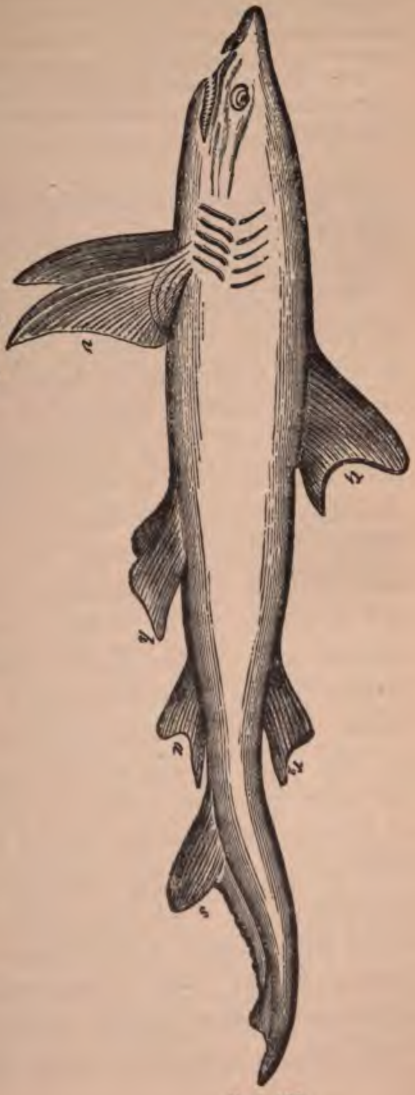


FIG. 192.

FIG. 191.—Embryo of a Shark (*Scymnus lichia*), seen from ventral side: *v*, pectoral fins (in front of these five pairs of gill-openings); *h*, ventral fins; *a*, anal opening; *s*, tail fin; *k*, external gill-tufts; *d*, yelk-sac (the greater part of this has been removed); *g*, eye; *n*, nose; *m*, mouth fissure.

FIG. 192.—Developed Man-shark (*Carcharias melanopterus*), seen from the left side: r_1 first, r_2 second dorsal fin; *s*, tail fin; *a*, anal fin; *v*, pectoral fins; *h*, ventral fins.

developed in another direction from the Primitive Fishes; this line leads upward through the Dipneusta group to the important class of Amphibia.

This significant relationship between the three groups of Fishes has been placed beyond all doubt by the researches of Gegenbaur on the subject. The lucid discussion on the "systematic position of the Selachii" which that author inserted in the introduction to his classic study of the "head skeleton of the Selachii," must be regarded as definitely proving this important relation.[148] In Primitive Fishes (*Selachii*), however, the scales (skin appendages) and the teeth (jaw appendages) are identical in formation and structure, while in the other two groups of Fishes (Mucous and Osseous Fishes) these organs have already become distinct and differentiated. Moreover, in Primitive Fishes, the cartilaginous skeleton (the vertebral column and the skull, as well as the members) is of the simplest and most primitive nature, of which the bony skeletons of Mucous and Osseous Fishes must be regarded as a modification. It is true that in certain respects (in the structure of the heart and of the intestinal canal) Mucous Fishes fully coincide with Primitive Fishes, and differ from Osseous Fishes. But a comparative review of all the anatomical relations plainly shows that the Mucous Fishes constitute a connecting group between Primitive and

Osseous Fishes. The Primitive Fishes (*Selachii*) form the most ancient and original group of Fishes. From these, in one direction, all other Fishes have developed; the Mucous Fishes first, which, at a much later period (in the Jurassic, or the Chalk Period), gave rise to the Osseous Fishes. In another direction, the Primitive Fishes gave rise to the parent-forms of the higher Vertebrates, directly to the Dipneusta, and thus to Amphibians. Regarding the Selachii as forming the eleventh stage in our pedigree, these would be followed by the Dipneusta group as the twelfth stage, and by the Amphibian group as the thirteenth stage.

The advance effected in the development of the Mud-fishes (*Dipneusta*) from the Primitive Fishes is of great moment, and is connected with a very noticeable change, which took place in the beginning of the Palæozoic, or Primary Period in organic life as a whole. For the very numerous fossil remains of plants and animals which are now known to belong to the first three epochs of the history of the earth—to the Laurentian, the Cambrian, and the Silurian Periods, are exclusively those of aquatic plants and animals. From this palæontological fact, taken in connection with certain weighty geological and biological considerations, we may infer, with tolerable certainty, that at that time no land animals yet existed. During the whole of the enormous Archizoic Period—during many millions of years—the living population of our globe were all water-dwellers: a very remarkable fact, when it is remembered that this period embraces the larger half of the entire organic history of the earth. The lower animal tribes are even now exclusively, or with very few exceptions, aquatic. But during the Archizoic, or Primordial Epoch, the higher animal tribes continued exclusively adapted to aquatic habits of life. It was not till later that they adopted a land life. The earliest fossils of terrestrial animals occur in the Devonian strata, which were deposited in the beginning of the second great division of the earth's history (the Palæozoic Epoch). They increase greatly in number in the deposits of the Coal and Permian Periods. Even in these early formations many terrestrial and air-breathing species, both of the Arthropod and of the Vertebrate tribe, occur; while their aquatic ancestors of the Silurian Period breathed nothing but water. This physiologically significant modification of the mode of respiration is the most influential change that affected the animal organism in the transition from water to dry land. In the first place it caused the development of an air-breathing organ, the lung, the water-breathing gills having previously acted as respiratory organs. Simultaneously, however, it effected a remarkable change in the circulation of the blood and in the organs connected with this; for these are always most closely correlated with the respiratory organs. In addition to these, other organs also, either in consequence of more remote correlation with the respiratory organs, or in consequence of new adaptations, were more or less modified.

Within the Vertebrate tribe it was undoubtedly a branch of the Primitive Fishes (*Selachii*) which, during the Devonian Period, made the first successful effort to accustom itself to terrestrial life and to breathe atmospheric air. In this the swimming-bladder was especially of service, for it succeeded in adapting itself to respiration of air, and so became a lung. The immediate consequence of this was the modification of the heart and nose. While true Fishes have only two blind nose-pits on the surface of the head, these now became connected with the mouth-cavity by an open passage. A canal formed on each side, leading directly from the nose-pit into the mouth-cavity, and thus even while the mouth-opening was closed the necessary atmospheric air could be introduced into the lungs. While, moreover, in all true Fishes the heart consists simply of two compartments, an auricle, which receives the venous blood from the veins of the body, and a ventricle, which forces this blood through an arterial expansion into the gills, the auricle, owing to the formation of an incomplete partition wall, is now divided into a right and a left half The right auricle alone now received the venous blood of the body, while the left auricle received the pulmonic venous blood passing from the lungs and the gills to the heart. The simple blood-circulation of the true Fishes thus became the so-called double circulation of the higher Vertebrates; and this development resulted, in accordance with the laws of correlation, in further progress in the structure of other organs.

The vertebrate class, which thus first adapted itself to the habit of breathing air, and which originated from a branch of the Selachii, are called Mud-fishes (*Dipneusta*), or Double-breathers, because, like the lowest Amphibia, they retain the earlier mode of breathing through the gills, in addition to the newly acquired lung-respiration. This class must have been represented by numerous and diverse genera during the Palæolithic Epoch (during the Devonian, Carboniferous, and Permian Periods). As, however, the skeleton is soft and cartilaginous, like that of the Selachii, they naturally left no fossil remains. The hard teeth of single genera (*Ceratodus*) could alone endure; these occur, for instance, in the Trias. At the present time there are only three extant genera of this whole class: *Protopterus annectens*, in the rivers of tropical Africa (White Nile, Niger, Quillimane, etc.); *Lepidosiren paradoxa*, in tropical South America (in the tributaries of the Amazon); and *Ceratodus Fosteri*, in the swamps of Southern Australia (Plate XII.).[149] This wide distribution of the three isolated descendants of the class is alone sufficient to prove that they are the last remnants of a group which was formerly very widely developed. The whole structure of their bodies shows that the group to which they belong forms the transition between Fishes and Amphibia. The direct transitional structure between the two classes is so clearly expressed in the whole organization of these curious animals, that zoologists yet dispute whether the Dipneusta are Fishes or Amphibia. Some well-known zoologists still class them among Amphibia, while they are usually placed among Fishes. In fact, the characters of both the classes are so united in the Dipneusta that the answer to the question as to their nature depends entirely upon the meaning attached to the terms "Fish" and "Amphibian." In their mode of life they are true Amphibia. During the tropical winter, in the rainy season, they swim in the water like Fishes and inhale water through the gills. During the dry season they burrow in the mud as it dries up, and during that period breathe air through lungs, like Amphibians and higher Vertebrates. In this two-fold respiration they do, it is true, coincide with the lower Amphibia, and stand far above Fishes. Yet, in most other characters they more nearly resemble the latter, and stand below the former. Their external appearance is entirely like that of Fishes.

The head of the Dipneusta is not distinct from the trunk. The skin is covered with large fish-scales. The skeleton is soft, cartilaginous; its development has been arrested at a very low stage, just as in the lower Primitive Fishes. The notochord is retained entire. The two pairs of limbs are very simple fins of primitive structure, like those of the lowest Primitive Fishes. The structure of the brain, of the intestinal tube, and the sexual organs, is also as in Primitive Fishes. The Dipneusta, or Mud-fishes, have, therefore, by heredity, accurately retained many features of a lower organization derived from our primæval Fish ancestors, while their adoption of the habit of breathing air through lungs introduced a great advance in the vertebrate organization.

Moreover, the three extant Mud-fishes differ a good deal from one another in important points of structure. The Australian Mud-fish (*Ceratodus*), which was first described at Sidney in 1870 by Gerard Krefft, and which attains a length of six feet, appears in an especial degree to represent a primæval and very conservative animal form (Plate XII.). This is especially true of the structure of its simple lung, and of its fins, which contain a pinnate skeleton. In the African Mud-fish (*Protopterus*), on the contrary, and in the American form (*Lepidosiren*) the double lung is present, as in all higher Vertebrates; nor is the fin-skeleton pinnate. In addition to the internal gills, Protopterus has also external gills, which are wanting in Lepidosiren. Those unknown Dipneusta, which were among our direct ancestors, and which formed the connecting link between the Selachii

TABLE XX.

Systematic Survey of the Phylogenetic Classification of Vertebrates.

I. **Skull-less** (**Acrania**), *or* **Tube-hearted** (**Leptocardia**).
Vertebrates without a specialized head, skull, brain, or centralized heart.

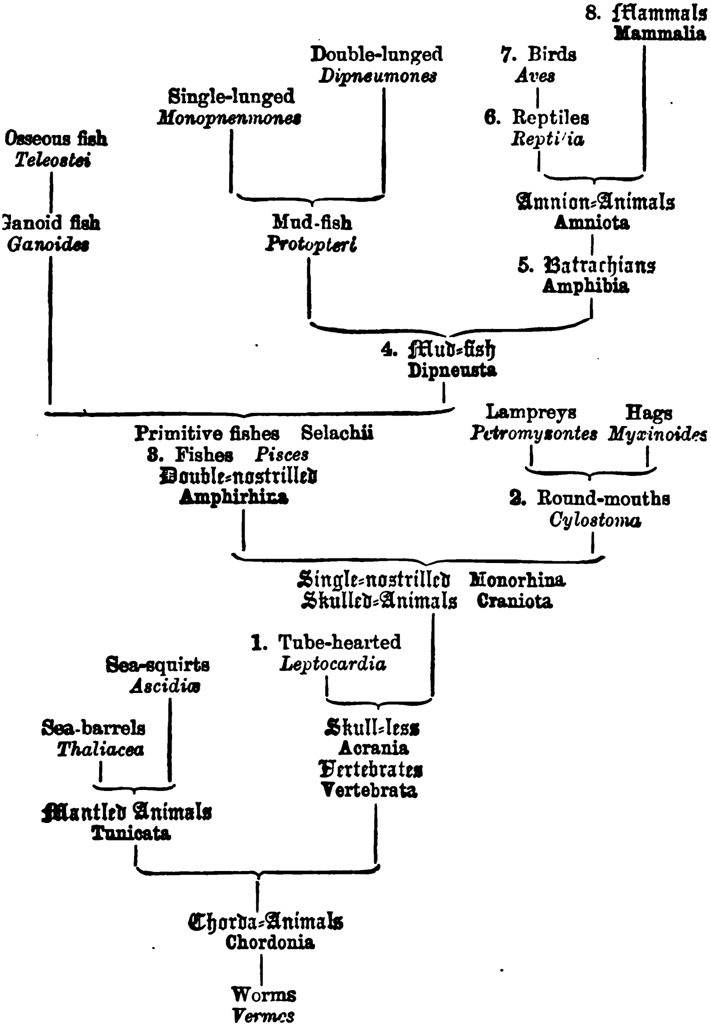
1. Skull-less **Acrania**	I. Tube-hearted *Leptocardia*	1. Lancelets	1. Amphioxida

II. **Animals with skulls** (**Craniota**) and with **centralized hearts** (**Pachycardia**).
Vertebrates with specialized head, with skull and brain, and with a centralized heart.

Main-classes of the Skulled Animals.	*Classes of the Skulled Animals.*	*Sub-classes of the Skulled Animals.*	*Systematic Name of the Sub-classes.*
2. Single-Nostrilled **Monorhina**	II. Round months *Cyclostoma*	2. Hags, or Mucous Fish	2. Hyperotreta (Myxinoida)
		3. Lampreys	3. Hyperoartia (Petromyzontia)
3. Non-amnionate **Anamnia**	III. Fishes *Pisces*	4. Primitive Fish	4. Selachii
		5. Ganoid Fish	5. Ganoides
		6. Osseous Fish	6. Teleostei
	IV. Mud-fishes *Dipneusta*	7. Single-lunged	7. Monopneumones
		8. Double-lunged	8. Dipneumones
	V. Batrachians *Amphibia*	9. Mailed Batrachians	9. Phractamphibia
		10. Naked Batrachians	10. Lissamphibia
4. Amnion-Animals **Amniota**	VI. Reptiles *Reptilia*	11. Lizards	11. Lacertilia
		12. Snakes	12. Ophidia
		13. Crocodiles	13. Crocodilia
		14. Tortoises	14. Chelonia
		15. Sea-dragons	15. Halisauria
		16. Dragons	16. Dinosauria
		17. Flying Reptiles	17. Pterosauria
		18. Beaked Animals	18. Anomodonta
	VII. Birds *Aves*	19. Long-tailed	19. Saururæ
		20. Fan-tailed	20. Carinatæ
		21. Bush-tailed	21. Ratitæ
	VIII. Mammals *Mammalia*	22. Cloacal Animals	22. Monotrema
		23. Pouched Animals	23. Marsupialia
		24. Placental Animals	24. Placentalia

TABLE XXI.

Pedigree of Vertebrates. (Cf. Plate XV.)



and the Amphibians, were doubtless in many respects different from their three direct descendants of the present time, but in the most essential characters they must have coincided with the latter. Unfortunately, the germ-history of the three surviving Mud-fishes is as yet entirely unknown; probably at some future time it will afford us further important information as to the tribal history of the lower Vertebrates and so of our ancestors.

Very important information of this kind has been supplied by the next Vertebrate class, that of the Batrachians (*Amphibia*), which is directly connected with the Dipneusta, from which it originated. To this class belong the Axolotl, Salamanders (Plate XIII.), Toads, and Frogs. Formerly, after the example of Linnæus, all Reptiles (Lizards, Snakes, Crocodiles, and Tortoises) were also classed among Amphibia. But these animals are of a far higher organization, and in the most important characters of their anatomical structure are more nearly allied to Birds than to Amphibians. The true Amphibia, on the other hand, are more nearly allied to the Double-breathers and to Primitive Fishes: they are also much older than Reptiles. Even as early as the Carboniferous Period numerous very highly developed Amphibia (some of large size) were extant, whereas the earliest Reptiles first appear only towards the close of the Permian Period. In all probability the Amphibia were developed from Double-breathers at an even earlier period—during the Devonian Period. The extinct Amphibia, of which fossil remains have been preserved from that most ancient Primæval Epoch—and these are especially numerous in the Trias—were distinguished by a large bony coat of mail overlying the skin (like that of the Crocodile), while most of the yet extant Amphibians have a smooth and slippery skin. The latter, also, are on an average smoother than the former, and must be regarded as their stunted posterity.

Among the Amphibia of the present time we are, therefore, unable to find any forms that are directly referable to the pedigree of the human race, or that are to be regarded as ancestors of the three higher Vertebrate classes; yet, in important points of their internal anatomical structure, and especially in their germ-development, they correspond so closely with us, that we are justified in affirming that between the Double-breathers (*Dipneusta*) on the one hand, and the three higher Vertebrate classes (grouped together as Amniota) on the other, there existed a series of extinct intermediate forms which, if we had them before us, we should class among Amphibia. The whole organization of the extant Amphibia represents a transitional group of this kind. In the important matters of respiration and circulation of the blood, they are still closely allied to the Double-breathers, although in other respects they rise above the latter This is especially true with respect to the advanced structure of their limbs or extremities. The latter here for the first time appear as feet with five digits. The thorough researches of Gegenbaur have shown that the fins of Fishes, concerning which very erroneous views were previously held, are feet with numerous digits; that is to say, the several cartilaginous or osseous rays, many of which occur in every Fish-fin, correspond to the fingers or digits on the limbs of higher Vertebrates. The several joints of each ray correspond to the several joints of each digit. In the Double-breathers the fin yet retains the same structure as in Fishes, and it was only gradually that the five-toed form of foot, which occurs for the first time in Amphibians, was developed from this multi-digitate form. This reduction in the number of the digits from ten to five occurred in those Dipneusta which must be regarded as the parent-forms of the Amphibia, probably as early as the latter half of the Devonian Period—or, at latest, in the immediately subsequent Carboniferous Period. Several fossil Amphibia with five digits have already been found in the strata of the latter period. Fossil footprints of the same animals are very numerous in the Trias (*Cherotheriun*).

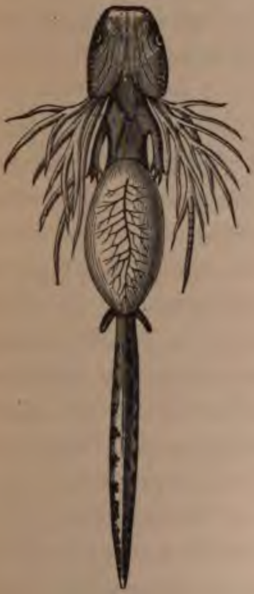
The great significance of the five digits depends on the fact that this number has been transmitted from the Amphibia to all higher Vertebrates. It would be impossible to discover any reason why in the lowest Amphibia, as well as in Reptiles and in higher Vertebrates up to Man, there should always originally be five digits on each of the anterior and posterior limbs, if we denied that heredity from a common five-fingered parent-form is the efficient cause of this phenomenon: heredity can alone account for it. In many Amphibia, certainly, as well as in many higher Vertebrates, we find less than five digits. But in all these cases it can be shown that separate digits have retrograded, and have finally been completely lost.

The causes which effected the development of the five-fingered foot of the higher Vertebrates in this Amphibian parent-form from the many-fingered foot, must certainly be found in the adaptation to the totally altered functions which the limbs had to discharge during the transition from an exclusively aquatic life to one which was partially terrestrial. While the many-fingered fins of the Fish had previously served almost exclusively to propel the body through the water, they had now also to afford support to the animal while creeping upon land. This effected a modification both of the skeleton and of the muscles of the limbs. The number of fin rays was gradually lessened, and was finally reduced to five. These five remaining rays now, however, developed more vigorously. The soft cartilaginous rays became hard bones. The rest of the skeleton also became considerably more firm. The movements of the body became not only more vigorous, but also more varied. The separate portions of the skeleton system, and consequently those of the muscular system also, became more and more differentiated. Owing to the intimate correlation of the muscular to the nervous system, the latter also naturally made marked progress in point of function and structure. We therefore find that the brain is very much more developed in the higher Amphibia than in Fishes, in Mud-fishes, and in the lower Amphibia.

The organs which are most modified in consequence of an amphibious mode of life are, as we have already seen in the Double-breathers (*Dipneusta*), those of respiration and of the circulation of the blood. The first advance in organization necessitated by the transition from aquatic to terrestrial habits of life was, of course, the formation of an air-breathing organ, a lung. This developed directly from the swimming-bladder which these animals had inherited from the Fishes. At first the function of this organ would be quite subordinate to the more ancient organ, used for the respiration of water, the gills. Hence we find that the lowest Amphibia, the Gilled Amphibia, like the Dipneusta, spend the greater part of their lives in the water, and that accordingly they breathe water through gills. It is only for brief intervals that they rise to the surface of the water or creep out of the water on to the land; and at these times they breathe air through lungs. Some, however, of the Tailed Amphibians, the Axolotl and the Salamander, live exclusively in the water only when young, and afterwards usually remain on land. In the adult state they breathe only air through lungs. This is also the case with the most highly developed Amphibians, the Frog-amphibia (Frogs and Toads); some of the latter have even entirely lost the gilled larval form.[153] The same is true of a few small snake-like Amphibia, the Cæciliæ, which, like earth-worms, live in the ground.

The high degree of interest attached to the natural history of the Amphibian class is especially due to the fact that they hold a position exactly intermediate between the higher and the lower Vertebrates. While the lower Amphibia are in their whole organization directly allied to the Dipneusta and the Fishes, living mostly in the water and respiring water through gills, the higher Amphibia are no less directly related to the Amnion Animals, for, like the latter, they live mostly on land, and breathe air through lungs. But when young the higher forms resemble the lower, and only attain their own higher degree of development after undergoing complete modification. The individual germ-history of most higher Amphibians still accurately reproduces the tribal history of the whole class; and the various stages of modification which were necessitated in certain low Vertebrates by the transition from aquatic to terrestrial habits during the Devonian or Carboniferous Period, are still to be seen every spring in each Frog as it develops from the egg in our ditches and pools.

Like the Tailed Salamanders (Fig. 193), each common Frog emerges from the egg in a larval form, totally different from that of the full-grown Frog (Fig. 194). The short



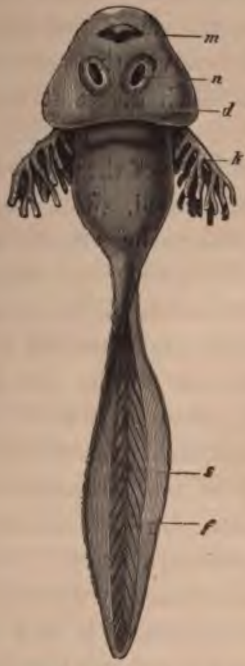


FIG. 193.—Larva of Spotted Land-Newt (*Salamandra maculata*), from the ventral side. In the centre a yelk-sac yet protrudes from the intestine. The external gills are prettily branched and tree-like. The two pairs of limbs are yet very small.

FIG. 194.—Larva of the Common Grass-Frog (*Rana temporaria*), a so-called tadpole: *m*, mouth; *n*, a pair of suction cups used in clinging to stones; *d*, skin-fold, which gives rise to the gill-roof; behind are the gill-openings, from which the gill branches protrude; *s*, tail-muscles; *f*, skin-fold of the tail, forming a float.

trunk is produced into a long tail, which in form and structure resembles the tail of a Fish (*s*). At first it has no limbs. Respiration is accomplished solely by gills, which are at first external (*k*) and afterwards internal. Correspondingly, the heart is also of the same form as in the Fishes, and consists of only two compartments—an auricle, which receives the venous blood of the body, and a ventricle, which drives it through the arterial bulb into the gills.

Numbers of these fish-like Frog larvæ, or "tadpoles," as they are called, swim about every spring in all ponds and pools, using their muscular tails for propulsion, just as is done by Fishes and larval Ascidians. The remarkable transformation of the fish-like form into that of the Frog does not take place till after the tadpole has grown to a certain size. From the throat grows a closed sac which develops into a pair of large sacs; these are the lungs. The simple chamber of the heart is divided into two auricles, owing to the formation of a partition wall, and simultaneously considerable changes of structure occur in the main arterial trunks. Previously all the blood passed from the heart-chamber through the aorta arches into the gills; but only part of it now passes to the gills, while another part passes through the newly formed lung arteries into the lungs. From the lungs arterial blood returns into the left auricle of the heart, while the venous blood of the body collects in the right auricle. As both of the auricles open into the simple ventricle, the latter contains mixed blood. The fish-like form has now passed into the Dipneusta form. During the further course of modification the gills, with the gill-vessels, are entirely lost, and respiration is now performed by the lungs alone. Yet later, the long tail is also rejected, and the Frog now leaps about on the land on legs which have sprouted in the mean time.[150]

This remarkable metamorphosis of the higher Amphibia is very instructive in its bearing on Man's ancestral history, and is especially interesting owing to the fact that the various groups of extant Amphibia have remained stationary at various stages of their tribal history, which, in accordance with the fundamental law of Biogeny, are reproduced in this germ-history. First, there is a very low order of Amphibia, the Gilled Batrachians (*Sozobranchia*), which, like Fishes, retain their gills throughout life. To this order belong, among others, the well-known blind "Olm" of the Adelsberg Cave (*Proteus anguineus*), the Mud-eel of South Carolina (*Siren lacertina*), and the Axolotl of Mexico (*Siredon pisciformis;* Plate XIII. Fig. 1). All these Gilled Batrachians are fish-like animals with long tails, and in point of respiratory organs and of circulation of the blood they remain throughout life stationary at the Dipneusta stage. They possess both gills and lungs, and can either respire water through the gills or air through the lungs, as occasion requires. In another order, the Salamanders, the gills are lost during metamorphosis, and in the adult state air only is breathed through lungs. This order bears the name of Tailed Batrachians (*Sozura*) because they retain the tail throughout life. To this order belong the common Water-Newts (*Triton*) which swarm in all ponds during the summer, and the black, yellow-speckled Land-Salamanders (*Salamandra*) found in damp woods (Plate XIII. Fig. 2). The latter are among the most remarkable of our indigenous animals, sundry anatomical characters proving them to be very ancient and highly conservative Vertebrates.[151] A few Tailed Batrachians retain the gill-opening in the side of the neck, though the gills themselves are lost (*Menopoma*). If the larvæ of the Salamanders (Fig. 193) and Tritons are compelled to remain in water, and not allowed to get on land, they may, under favourable conditions, be made to retain their gills. In this fish-like condition they become sexually mature, and will throughout life remain compulsorily in the lower stage of development of the Gilled Batrachians. The opposite experiment was made some years ago in the case of the Mexican Gilled Batrachian, the fish-like Axolotl (*Siredon pisciformis;* Plate XIII. Fig. 1). This animal had previously been regarded as a permanent Gilled Batrachian, remaining throughout life in this fish-like condition. But of the hundreds of these animals kept in the Jardin des Plantes at Paris, a few individuals, for some unknown reason, crept to land, lost their gills, and changed into a form closely allied to that of the Salamander (*Amblystoma,* Fig. 2). In this state they became sexually mature.[152] This phenomenon, which at first excited a lively interest, has since been repeatedly observed with care. Zoologists regarded the fact as something peculiarly wonderful, though each spring every common Frog and Salamander passes through the same modification. In these animals we can in the same way follow each step in the significant metamorphosis of the aquatic and gill-respiring animal into the terrestrial and lung-respiring animal. That which thus takes place in the individual during germ-evolution; took place in the same way in the whole class during the course of its tribal history.

The metamorphosis which takes place in the third order

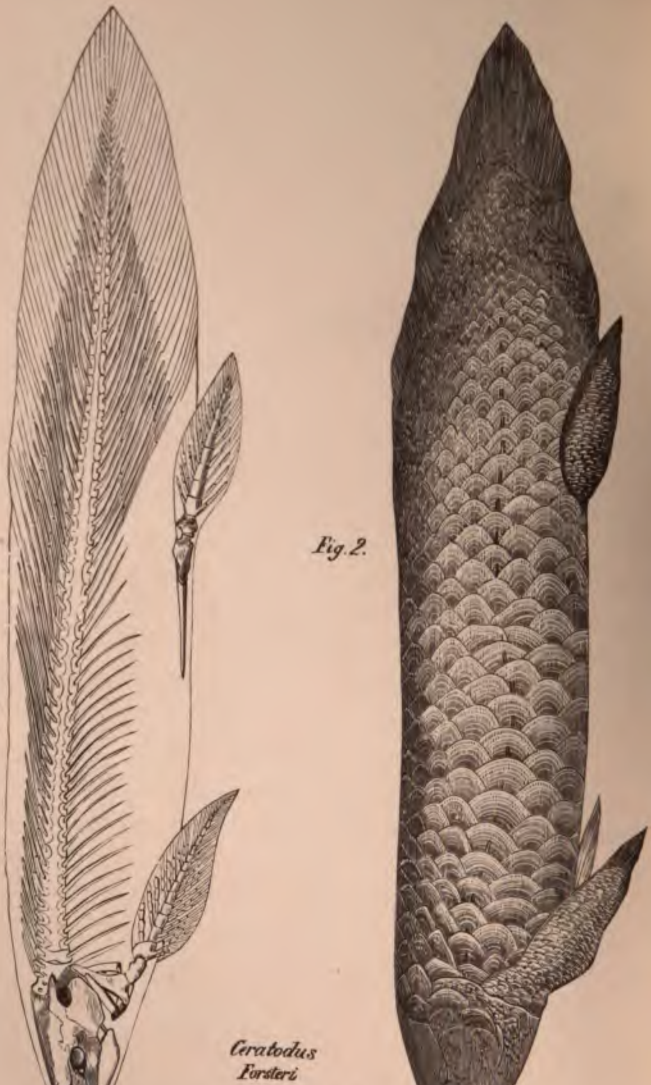


Fig. 1

Fig. 2.

Ceratodus Forsteri

Fig. 1.

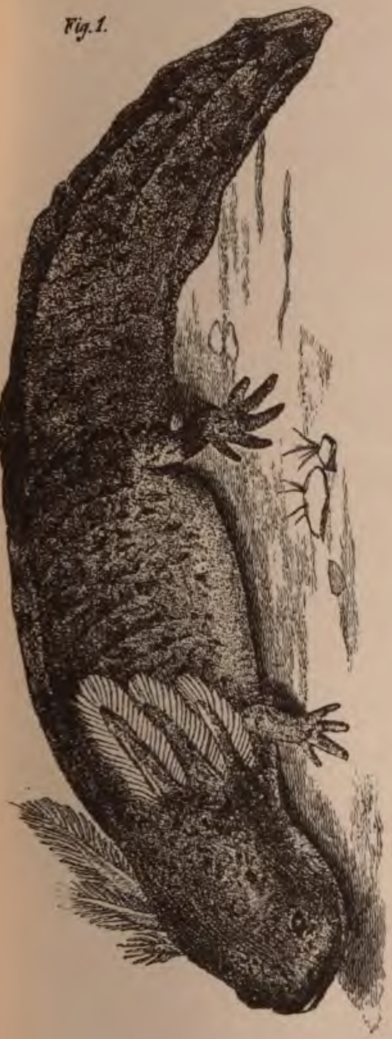


Fig. 1. Siredon *pisciformis*.

Fig. 2

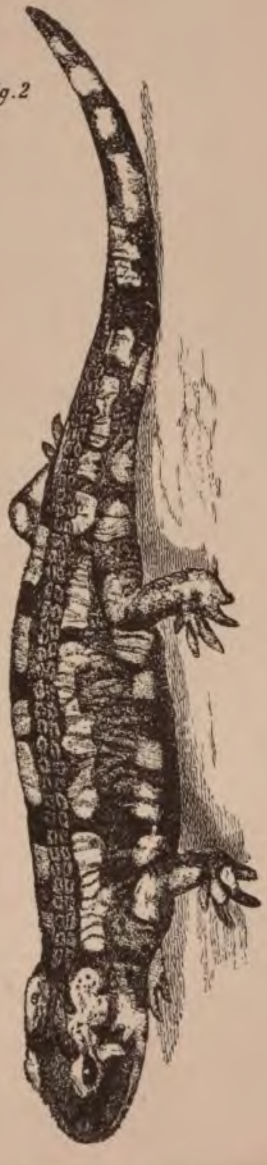


Fig. 2. Salamandra maculata.

of Amphibia, the Frog Batrachians (*Batrachia*, or *Anura*), is yet more complete than in the Salamanders. To these belong all the various kinds of Toads, Water-frogs, Tree-frogs, etc. In the course of transformation these lose not only the gills, but also the tail, which drops off in some cases earlier, in others later. In this respect the various species differ somewhat from one another. In most Frog Batrachians the larvæ drop the tail very early, and the tail-less frog-like form subsequently grows considerably larger. Other species, on the contrary, as, for instance, the *Pseudes paradoxus* of Brazil, as also an European Toad (*Pelobates fuscus*) remain for a very long time in the fish form, and retain a lengthy tail till they have almost attained their full size; hence, after their metamorphosis is completed, they appear much smaller than before. The opposite extreme is seen in some Frogs but recently brought under notice, which have lost the whole of their historic metamorphoses, and in which no tailed and gilled larva emerges from the egg, but the perfect Frog, without tail or gills. These Frogs inhabit isolated oceanic islands, the climate of which is very dry, and which are often for a considerable length of time without fresh water. As fresh water is indispensable for gill-respiring tadpoles, these Frogs have adapted themselves to this local deficiency and have entirely relinquished their original metamorphosis, *e.g.*, *Hylodes martinicensis*.[158]

The ontogenetic loss of gills and tail in Frogs and Toads can of course only be phylogenetically explained as owing to the fact that these animals have descended from long-tailed salamander-like Amphibians. This is also proved beyond doubt by the Comparative Anatomy of the two groups. This remarkable transformation is, in other respects also, of general interest, as throwing a flood of light upon the Phylogeny of the Tail-less Apes and of Man. Man's ancestors were also long-tailed gill-breathing animals, resembling Gilled Batrachians, as is irrefutably demonstrated by the tail and the gill arches in the human embryo.

During the Palæozoic Epoch, and probably in the Carboniferous Period, there is no doubt that the Amphibian class embraced a series of forms which must be regarded as direct ancestors of Mammals, and so of Man. On grounds derived from Comparative Anatomy and Ontogeny, we must not, however, look for these Amphibian ancestors of ours—as might perhaps be supposed—among the Tail-less Frog Batrachians, but only among the lower Tailed Amphibians. We can with certainty point to at least two extinct Batrachian forms as direct ancestors of Man, as the thirteenth and fourteenth stages in our pedigree. The thirteenth ancestral form must have been closely allied to the Double-breathers (*Dipneusta*), must, like these, have possessed permanent gills, but must have been already characterized by having five digits on each foot; and were they still living we should place them in the group of Gilled Batrachians, with the Proteus and the Axolotl (Plate XIII. Fig. 1). The fourteenth ancestral form, on the other hand, must indeed have retained the long tail, but must have lost the gills, and hence the nearest allied forms among extant Tailed Batrachians would be the Water-Newts and Salamanders (Plate XIII. Fig. 2). Indeed, in the year 1725 the fossil skeleton of one of these extinct Salamanders (closely allied to the present giant Salamander of Japan) was described by the Swiss naturalist, Scheuchzer, as the skeleton of a fossil Man dating from the Deluge! ("Homo diluvii testis."[154])

As the vertebrate form occurring in our pedigree immediately after these Batrachian ancestors—and, therefore, as the fifteenth stage—let us now examine a lizard-like animal, of which no fossil remains have been obtained, and which is not even proximately represented in any extant animal form, but the former existence of which we may infer with the utmost certainty from certain comparative anatomical and ontogenetical facts. This important animal form we will call the *Protamnion*, or Primitive Amniotic animal. All Vertebrates higher than the Amphibia—that is, the three classes of Reptiles, Birds, and Mammals—are so essentially distinct in their whole structure from all the lower Vertebrates which we have as yet considered, and, on the other hand, have so much in common, that we may class them together in one group as Amnion Animals (*Amniota*). It is only in these three classes of animals that we find that remarkable envelope of the embryo known as the amnion. (Cf. vol. i. p. 386.) The latter must probably be regarded as a kenogenetic adaptation, as caused by the sinking of the embryo into the yelk-sac.[155]

All known Amnion Animals, all Reptiles, Birds, and Mammals (Man included), coincide in so many important points of organization and development that we are fully justified in asserting their common descent from a single parent form. If the testimony of Comparative Anatomy and Ontogeny is entirely unquestionable in any point, it is certainly so here. For all the special peculiarities and characters, which appear accompanying and following the formation of the amnion, and which we found in the development of the human embryo; all the many peculiarities in the development of the organs which we shall presently notice in detail; and, finally, the chief special arrangements of the internal structure of the body in all fully developed Amnion Animals; all these so clearly demonstrate the common origin of all Amnion Animals from a single extinct parent-form, that it is impossible to conceive their origin as polyphyletic, and that they originated from several independent parent-forms. This unknown common parent-form is the Primitive Amnion Animal (*Protamnion*). In external appearance the Protamnion was most probably an intermediate form between the Salamanders and the Lizards.

It was probably during the Permian Period that the Protamnion originated; perhaps at the beginning, perhaps at the close of that period. This we know from the fact that the Amphibia did not attain their full development till the Carboniferous Period, and that toward the close of the Permian the first fossil Reptiles make their appearance—or, at least, fossils (*Proterosaurus, Rhopalodon*) which must in all probability be referred to lizard-like Reptiles. Among the great and pregnant modifications of the vertebrate organization determined during this period by the development of the first Amnion Animals from salamander-like Amphibians, the three following are especially important: the total loss of water-breathing gills and modification of the gill-arches into other organs; the formation of the allantois, or primitive urinary sac; and, finally, the development of the amnion.

The total loss of the respiratory gills must be regarded as one of the most prominent characters of all Amnion

Animals. All these, even such as live in the water, *e.g.*, whales, respire only air through lungs, never water through gills. While all Amphibians, with very few exceptions, in the young state retain their gills for a longer or shorter period, and breathe through gills for some time (if not always), from this point gill-respiration entirely ceases. Even the Protamnion must have entirely ceased to breathe water. The gill-arches, however, remain, and develop into very different organs (partly rudimentary); into the various parts of the tongue-bone, into certain portions of the jaw apparatus, the organ of hearing, etc. But no trace of gill-leaves, of real respiratory organs on the gill-arches, are ever found in the embryo of Amnion Animals.

With this total loss of the gills is probably connected the formation of another organ, which we have already described as occurring in human Ontogeny; this is the allantois, or primitive urinary sac. (See vol. i. p. 379.) In all probability the urinary bladder of the Dipneusta is to be regarded as the first beginning of the allantois. Even in the American Mud-fish (*Lepidosiren*) we find an urinary bladder, which grows from the lower wall of the posterior extremity of the intestine, and serves as a receptacle for the renal secretions. This organ has been inherited by the Amphibia, as may be seen in any Frog. But it is only in the three higher Vertebrate classes that the allantois attains a special development; in these it protrudes at an early period from the body of the embryo, forming a large sac filled with liquid, and traversed by a considerable number of large blood-vessels. This sac also discharges a portion of the nutritive functions. In the higher Mammals and in Man the allantois afterwards forms the placenta.

The formation of the amnion and the allantois, together with the total loss of the gills and the exclusive adoption of lung-respiration, are the most important characters by which all Amnion Animals are distinguished from the lower Vertebrates which we have been considering. In addition to these there are a few subordinate characters which are constantly inherited by Amnion Animals, and are altogether wanting in animals without an amnion. One striking embryonic character of the Amnion Animals is the great curvature of the head and neck of the embryo. In the Anamnia the embryo is from the first either nearly straight, or else the whole body is bent in a sickle-shaped curve corresponding to the curvature of the yelk sac, to which the embryo is attached by its ventral surface; but there are no marked angles in the longitudinal axis (Plate VI. Fig. *F*). In all Amnion Animals, on the contrary, the body is very noticeably bent at an early age, so that the back of the embryo is much arched outwards, the head pressed almost at right angles against the breast, and the tail inclined on to the abdomen. The tail extremity, as it bends inwards, approaches so near to the frontal side of the head, that the two often nearly touch (Plates VI. and VII.). This striking triple curvature of the embryonic body, which has already been considered when we studied the Ontogeny of Man, and in which we distinguished the skull-curve, neck-curve, and tail-curve (vol. i. p. 371), is a characteristic peculiarity common to the embryos of all Reptiles, Birds, and Mammals. But in the formation of many internal organs also, an advance is observable in all the Amnion Animals which ranks them above the highest of the non-amnionate forms. Above all, a partition wall forms within the simple ventricle of the heart, dividing it into a right and a left ventricle. In connection with the complete metamorphosis of the gill-arches, a further development of the organ of hearing takes place. A considerable advance is also noticeable in the development of the brain, the skeleton, the muscular system, and other parts. Finally, the reconstruction of the kidneys must be regarded as a most important modification. In all the lower Vertebrates as yet considered, we have found the primitive kidneys, which appear very early in the embryos of all higher Vertebrates up to Man, acting as a secretory or urinary apparatus. In Amnion Animals, however, these early primitive kidneys lose their function at an early period of embryonic life, and it is assumed by the permanent "secondary kidneys," which grow out of the terminal portion of the primitive kidney ducts.

Looking back at the whole of these characters of Amnion Animals, it is impossible to doubt that all animals of this group, all Reptiles, Birds, and Mammals, had a common origin, and constitute a single main division of kindred forms. To this division belongs our own race. In his whole organization and germ-history Man is a true Amnion Animal, and, in common with all other Amniota, has descended from the Protamnion. Although this whole group originated at the end, or perhaps even in the middle, of the Palæozoic Epoch, it did not attain its full development and its full perfection till the Mesozoic Epoch. The two classes of Birds and Mammals then first appeared. Nor did the Reptilian class develop in its full variety until the Mesozoic Epoch, which is, therefore, called the "Age of Reptiles." The unknown and extinct Protamnion, the parent-form of the entire group, must have been very nearly allied to the Reptiles in its whole organization, even though it cannot be regarded as a true Reptile in the present meaning of the term. Of all known Reptiles, certain Lizards are most nearly allied to the Protamnion; and in the outward form of its body we may imagine the latter as an intermediate form between the Salamander and the Lizard.[156]

The Comparative Anatomy and Ontogeny of the Amnionate group clearly explains its genealogy. The group which directly descended from Protamnion gave rise to two divergent branches. The first of these, which will in future receive our whole attention, forms the Mammalian group. The other branch, which assumed an entirely different course of progressive development, and which is connected with the mammalian branch only as the root, is the comprehensive group constituted by Reptiles and Birds. The two latter forms may be classed together as *Monocondylia*, or *Sauropsides.* The common parent-form of these is an extinct lizard-like Reptile. From this, the Serpents, Crocodiles, Tortoises, Dragons, etc.—in short, all the various forms of the Reptilian group—developed in different directions. The remarkable group formed by the Birds also developed directly from an offshoot of the Reptilian group, as is now definitely proved. Down to a late time the embryos of Reptiles and of Birds are yet identical, and even later they are in some respects surprisingly similar. (See Plate VI. Fig. *T* and *C*.) In their entire organization the resemblance between the two is so great that no anatomist now denies that the Birds originated from Reptiles. The Mammalian line is connected at its roots with the Reptilian line, but afterwards diverged entirely from the latter, and developed in an entirely peculiar direction. The highest result of the development of the Mammalian line is Man, the so-called "Crown of Creation."

CHAPTER XIX.

THE PEDIGREE OF MAN.

IV. FROM THE PRIMITIVE MAMMAL TO THE APE.

The Mammalian Character of Man.—Common Descent of all Mammals from a Single Parent-form (Promammalian).—Bifurcation of the Amnion Animals into Two Main Lines: on the one side, Reptiles and Birds, on the other, Mammals.—Date of the Origin of Mammals: the Trias Period.—The Three Main Groups or Sub-classes of Mammals: their Genealogical Relations.—Sixteenth Ancestral Stage: Cloacal Animals (*Monotremata*, or *Ornithodelphia*).—The Extinct Primitive Mammals (*Promammalia*) and the Extant Beaked Animals (*Ornithostoma*).—Seventeenth Ancestral Stage: Pouched Animals (*Marsupialia*, or *Didelphia*).—Extinct and Extant Pouched Animals.—Their Intermediate Position between Monotremes and Placental Animals.—Origin and Structure of Placental Animals (*Placentalia*, or *Monodelphia*).—Formation of the Placenta.—The Deciduous Embryonic Membrane (*Decidua*).—Group of the *Indecidua* and of the *Deciduata*.—The Formation of the Decidua (*vera*, *serotina*, *reflexa*) in Man and in Apes.—Eighteenth Stage: Semi-apes (*Prosimiæ*).—Nineteenth Stage: Tailed Apes (*Menocerca*).—Twentieth Stage: Man-like Apes (*Anthropoides*).—Speechless and Speaking Men (*Mali. Homines*).

"A century of anatomical research brings us back to the conclusion of Linnæus, the great lawgiver of systematic zoology, that man is a member of the same order as the apes and lemurs. Perhaps no order of mammals presents us with so extraordinary a series of gradations as this, leading us insensibly from the crown and summit of the animal creation down to creatures from which there is but a step, as it seems, to the lowest, smallest, and least intelligent of the placental mammalia. It is as if nature herself had foreseen the arrogance of man, and with Roman severity had provided that his intellect, by its very triumphs, should call into prominence the slaves, admonishing the conqueror that he is but dust."—THOMAS HUXLEY (1863).

AMONG those zoological facts which afford us points of support in researches into the pedigree of the human race, the position of Man in the Mammalian class is one of the most important and fundamental. Much as zoologists have long disagreed in their opinions as to Man's particular place in this class, and especially in their ideas of his relation to the most nearly related group, that of the Apes, yet no naturalist has ever doubted that Man is a genuine Mammal in the whole structure and development of his body. Every anatomical museum, every manual of Comparative Anatomy, affords proof that the structure of the human body shares all those peculiarities which are common to all Mammals, and by which the latter are definitely distinguished from all other animals.

Now, if we examine this established anatomical fact phylogenetically, and in the light of the Theory of Descent, we arrive immediately at the conclusion that Man is of a common stock with all the other Mammals, and springs from a root common to them. The various characteristics in which all Mammals coincide, and in which they differ from all other animals, are, moreover, of such a kind, that a polyphyletic hypothesis appears in a special degree inadmissible in their case. It is inconceivable that all existing and extinct Mammals have sprung from several different and originally separate root-forms. We are compelled, if we in any way acknowledge the Theory of Evolution, to assume the monophyletic hypothesis, that all Mammals, including Man, must be traced from a single common mammalian parent-form. This long extinct primæval root-form and its immediate descendants—which differ from each other hardly more than do several species of one genus—we will call Primitive Mammals (*Promammalia*). As we have already seen, this root-form developed from the ancient parent-form of the Primitive Amnion Animals in a direction wholly different from that followed by the Reptile group, which afterwards gave rise to the more highly developed class of Birds. The differences which distinguish Mammals on the one side, from Reptiles and Birds on the other, are so important and characteristic, that we may quite safely assume a bifurcation of this kind in the vertebrate family tree. Reptiles and Birds—which we classed together as *Monocondylia*, or *Sauropsida*—coincide entirely, for instance, in the characteristic structure of the skull and brain, which is strikingly dissimilar from that of the same parts in Mammals. In Reptiles and Birds, the skull is connected with the first cervical vertebra (the atlas) by a single joint-process (condyle) of the occipital bone; in Mammals, on the contrary (as in Amphibians), the condyle is double. In the former, the under jaw is composed of many parts, and is connected with the skull by a peculiar bone of the jaw (the square bone) so as to be movable; in the latter, on the contrary, the lower jaw consists of but two bone-pieces, which are directly attached to the temporal bone. Again, the skin of the Sauropsida (Reptiles and Birds) is covered with scales or feathers, that of the Mammals with hair. The red blood-cells of the former are nucleated, those of the latter non-nucleated. The eggs of the former are very large, are provided with a large nutritive yelk, and undergo discoidal cleavage resulting in a Disc-gastrula; the eggs of the latter are very small, and their unequal cleavage results in the formation of a Hood-gastrula. Finally, two characters entirely peculiar to Mammals, and by which these are distinguished both from Birds and Reptiles and from all other animals, are the presence of a complete diaphragm, and of the milk-glands (*mammæ*), by means of which the new-born young are nourished by the milk of the mother. It is only in Mammals that the diaphragm forms a transverse partition-wall across the body-cavity (*cœloma*), completely separating the chest from the ventral cavity. (Cf. Plate V. Fig. 16 *z*.) It is only among Mammals that the mother nourishes the young with her milk; and the whole class are well named from this.

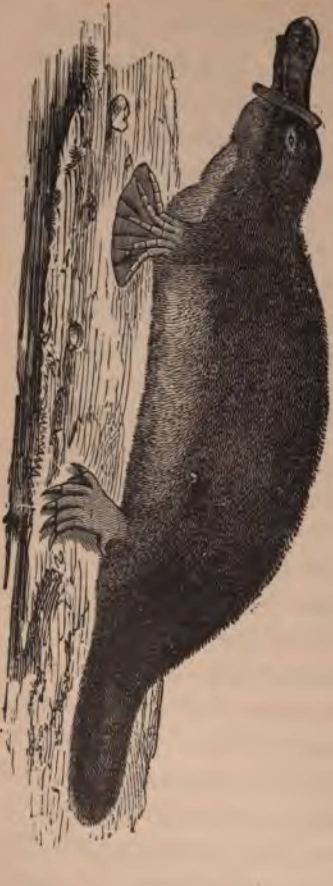
These important facts in Comparative Anatomy and Ontogeny clearly show that the tribe of Amnion Animals (*Amniota*) bifurcated from the very first into two main diverging lines; on the one side, the Reptilian line, from which the Birds afterwards developed; on the other side, the Mammalian line. The same facts also prove as indubitably that Man originated from the latter line. For Man, in common with Mammals, shares all the characteristics we have mentioned, and is distinguished by them from all other animals. And, finally, these facts indicate as certainly those advances in vertebrate structure by which one branch of the Primitive Amnion Animals developed into the parent-form of Mammals. The most prominent of these advances were (1) the characteristic modification of the skull and brain; (2) the formation of a covering of hair; (3) the complete development of the diaphragm; and (4) the formation of the milk-glands and the adaptation to the suckling of the young. Intimately connected with these, other important structural modifications gradually occurred.

The period at which these important advances, which laid the first foundation of the Mammalian class, took place, may most probably be placed in the first part of the Mesolithic, or Secondary Epoch, in the Triassic Period. For the oldest known fossil remains of Mammals occur in sedimentary rock-strata of the most recent deposits of the Triassic Period, in the upper Keuper. It is possible, indeed, that the parent-forms of Mammals may have appeared earlier (perhaps even at the close of the Palæolithic Epoch, in the Permian Period). But no fossil remains of Mammals belonging to that period are as yet known. Throughout the Mesolithic Epoch, throughout the Triassic, Jurassic, and Calcareous Periods, fossil remains of Mammals are very scarce, and indicate a very limited development of the whole class. During this Mesolithic Epoch, Reptiles play the chief part, and Mammals are of quite secondary importance. It is, however, especially significant and interesting, that all mammalian fossil remains of the Mesozoic Epoch belong to the older and inferior division of Pouched Animals (*Marsupialia*), a few probably even to the yet older division of the Cloacal Animals (*Monotrema*). Among them, no traces of the third and most highly developed division of the Mammals, the Placental Animals, have as yet been found. The last, to which Man belongs, are much more recent, and their fossil remains do not occur till much later—in the succeeding Cænolithic Epoch; in the Tertiary Period. This palæontological fact is very significant, because it harmonizes perfectly with that order of the development of Mammals which is unmistakably indicated by Comparative Anatomy and Ontogeny.

These show that the whole Mammalian class is divisible into three main groups, or sub-classes, corresponding to three successive stages of phylogenetic evolution. These three stages, which consequently represent three important ancestral stages in the human pedigree, were first distinguished in the year 1816 by the celebrated French zoologist, Blainville, who named them, according to the different structure of the female organs of reproduction, *Ornithodelphia*, *Didelphia*, and *Monodelphia* (δελφύς, which, being interpreted, is *uterus*). It is not, however, only in the varied structure of the sexual organs that these three classes differ from one another, but in many other respects also, so that we can safely maintain the important phylogenetic statement: The *Monodelphia*, or Placental Animals, have descended from the *Didelphia*, or Pouched Animals; and the latter, again, have descended from the Cloacal Animals, or *Ornithodelphia*.

Accordingly we have now to consider, as the sixteenth ancestral stage in the human pedigree, the oldest and lowest main group of Mammals; the sub-class of the Cloacal Animals (*Monotremata*, or *Ornithodelphia*). They are so named in consequence of the cloaca, which they have in common with the other lower Vertebrates. This so-called cloaca is the common excretory channel for the excrement, the urine, and the sexual products (Fig. 327). For, in these Cloacal Animals, the urinary duct and the sexual canals yet open into the posterior parts of the intestine, while in all other Mammals they are wholly separated from the rectum and anus, and open by a special orifice (*porus* *urogenitalis*). The urinary bladder in the Monotremes also opens into the cloaca, and is separate from the two urinary ducts (Fig. 327, *vo*); in all other Mammals the latter open directly into the urinary bladder. The structure of the milk-glands, by means of which all Mammals suckle their new-born young for a time, is also quite peculiar in the Cloacal Animals. In them the milk-gland has no nipple which the young animal can suck; there is only a peculiar sieve-like place in the skin, perforated with holes through which the milk passes out, and from which the young animal has to lick it. For this reason they have also been called Nipple-less Mammals (*Amasta*). Again, the brain of the Cloacal Animals has remained at a much lower stage of development than that of any other Mammal. The fore-brain, or cerebrum, is so small that it does not overhang the hind-brain, or cerebellum. In the skeleton (Fig. 196), the structure of the shoulder girdle, as well as of other parts, is remarkable, differing entirely from the same part in other Mammals, and resembling rather those of the lower Vertebrates, especially Reptiles and Amphibians. Like the latter, the Cloacal Animals have a well-developed coracoid bone (*coracoideum*), a strong bone uniting the shoulder-blade with the breast-bone. In all other Mammals the coracoid bone (as in Man) has degenerated, has coalesced with the shoulder-blade, and appears only as an insignificant process of the latter. These and many other less striking peculiarities prove beyond doubt that the Cloacal Animals occupy the lowest rank among Mammals, and represent a direct intermediate form between the Protamnia and other Mammals. All these marked Amphibian characters must have been present in the parent form of the whole vertebrate class, in the Primitive Mammal, by which they must have been inherited from the Primitive Amnion Animals.

During the Triassic and Jurassic Periods, the sub-class of the Cloacal Animals seems to have been represented by many Primitive Mammals of very varied form. At present it is represented only by two isolated members, which are grouped together as the Beaked Animal family (*Ornithostoma*). Both of these are confined to Australia and the neighbouring island of Van Diemen's Land, or Tasmania; both are becoming less numerous year by year, and will soon be classed, with all their blood relations, among the extinct animals of our globe. One of these forms passes its life swimming about in rivers, and builds subterranean dwellings on the banks: this is the well-known Duck-billed Platypus (*Ornithorhynchus paradoxus*): it is web-footed, has a thick, soft skin, and broad, flat jaws, which very much resemble a duck's bill (Figs. 195, 196). The other form, the Porcupine Ant-eater (*Echidna hystrix*), much resembles the Ant-eaters, in its mode of life, in the characteristic form of its slender snout, and in the great length of its tongue; it is covered with prickles, and can roll itself up into a ball like a hedgehog. Neither of these extant Beaked Animals possesses true bony teeth, and, in this point, they resemble the Toothless Mammals (*Edentata*). The absence of teeth, together with other peculiarities of the Ornithostomata, is probably the result of comparatively recent adaptation. Those extinct Cloacal Animals which embraced the parent-forms of the whole Mammalian class, the Promammalia, must certainly have been provided with a developed set of teeth, inherited from Fishes.[157] Some



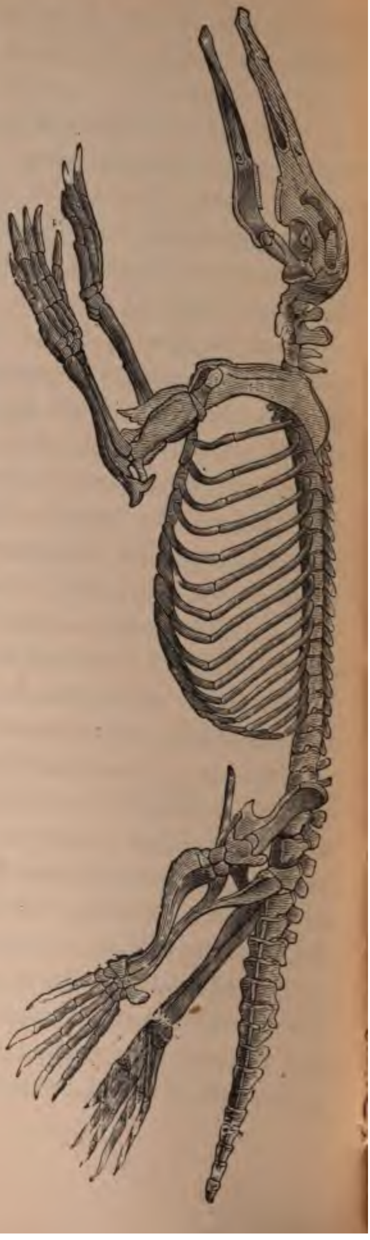


FIG. 195.—The Duck-billed Platypus (*Ornithorhynchus paradoxus*).
FIG. 196.—Skeleton of Platypus.

small single molars, found in the uppermost strata of the Keuper formation in England and Würtemberg, and which are the oldest known vertebrate remains, probably belong to these primæval Promammalia. These teeth, by their form, indicate species that lived on insects; the species has been called *Microlestes antiquus.* Teeth belonging to another closely allied Primitive Mammal (*Dromatherium silvestre*) have recently been discovered in the North American Trias.

On the one hand, the still extant Beaked Animals, and, on the other, the parent-forms of the Pouched Animals (*Marsupialia*, or *Didelphia*), must be regarded as representing two distinct and divergent lines of descent from the Promammalia. This second Mammalian sub-class is very interesting as a perfect link between the two other sub-classes. While the Pouched Animals, on the one side, retain many of the characters of the Cloacal Animals, they also, on the other, possess many placental characters. A few characters are quite peculiar to Pouched Animals alone; such, for instance, is the structure of the male and female sexual organs, and the form of the lower jaw The distinctive feature of the latter in these Pouched Animals is a peculiar hook-shaped bony process, passing inward horizontally from the angle of the lower jaw. As neither Cloacal Animals nor Placental Animals have this process, this structure is alone sufficient to distinguish the Pouched Animals (*Marsupialia*). Nearly all the known mammalian fossils from the Jurassic and Cretaceous formation are lower jaws. Our whole knowledge of numerous mesolithic mammalia, the former existence of which would otherwise never have been known, is solely derived from their fossilized lower jaws, no fragment of the rest of their bodies having been reserved. According to the logic usually applied to palæontology by the "exact" opponents of the theory of evolution, the inference drawn from this fact would be that these Mammals had no bones except lower jaws. The remarkable circumstance is, after all, very easily accounted for. The lower jaw of Mammals being a solid and exceptionally hard bone, but very loosely attached to the skull, it is easily detached from the carcase as the latter is carried down by some river, and, falling to the bottom, is retained in the mud. The rest of the carcase is carried on further, and is gradually destroyed. As all the mammalian lower jaws found, in England, in the Jurassic strata of Stonesfield and Purbeck, exhibit this peculiar process characteristic of the Pouched Animals (*Marsupialia*), we may infer, from this palæontological fact, that they belonged to Marsupials. No Placental Animals appear to have existed during the Mesolithic Epoch. At least no fossil remains, undoubtedly belonging to these and dating from that epoch, are known.

The extant Pouched Animals, the most generally known of which are the gramnivorous Kangaroos and the carnivorous Pouched Rats, display very considerable difference in their organization, in the form of their bodies and in size, and in many respects correspond to the several orders of Placental Animals. The great majority of them live in Australia, in New Holland, and in a few of the Australian and South Asiatic islands; some few species occur in America. On the other hand, there is no longer a single indigenous Pouched Animal on the continents of Asia, of Africa, or of Europe. The case was very different during the Mesolithic, and also during the earlier Cænolithic Epochs

The Neptunian deposits of these epochs in all quarters of the globe, and even in Europe, contain abundant marsupial remains in great variety, some of them being of very large size. From this we may infer that the extant Pouched Animals are but the last remnant of a group which was once much more widely developed, and which was distributed over the whole surface of the globe. During the Tertiary Period, these succumbed in the struggle for life with the stronger Placental Animals, and the survivors were gradually driven back by the latter into their present restricted area

From the Comparative Anatomy of the extant Pouched Animals, very important conclusions may be drawn as to their phylogenetic intermediate position between Cloacal Animals and Placental Animals. The incomplete development of the brain, especially of the fore-brain (*cerebrum*), the possession of marsupial bones (*ossa marsupialia*), the simple structure of the allantois (which does not as yet develop a placenta), with many other characters, have been inherited by the Pouched Animals from Cloacal Animals. On the other hand, they have lost the independent coracoid bone (*os coracoideum*) attached to the shoulder girdle. A more important step consists in the fact that a cloaca is no longer formed; the cavity of the rectum, together with the anal opening, is separated by a partition wall from the urinary and sexual opening (*sinus urogenitalis*). Moreover, all Pouched Animals develop special nipples on the milk-glands, which are sucked by the young after birth. These nipples project into the cavity of a pouch, or marsupium, in the ventral side of the mother. This pouch is supported by a couple of marsupial bones. In it the young, which are born in a very imperfect condition, are carried by the mother for a long time; until, in fact, they are completely developed (Fig. 197). In the large Giant Kangaroo, which

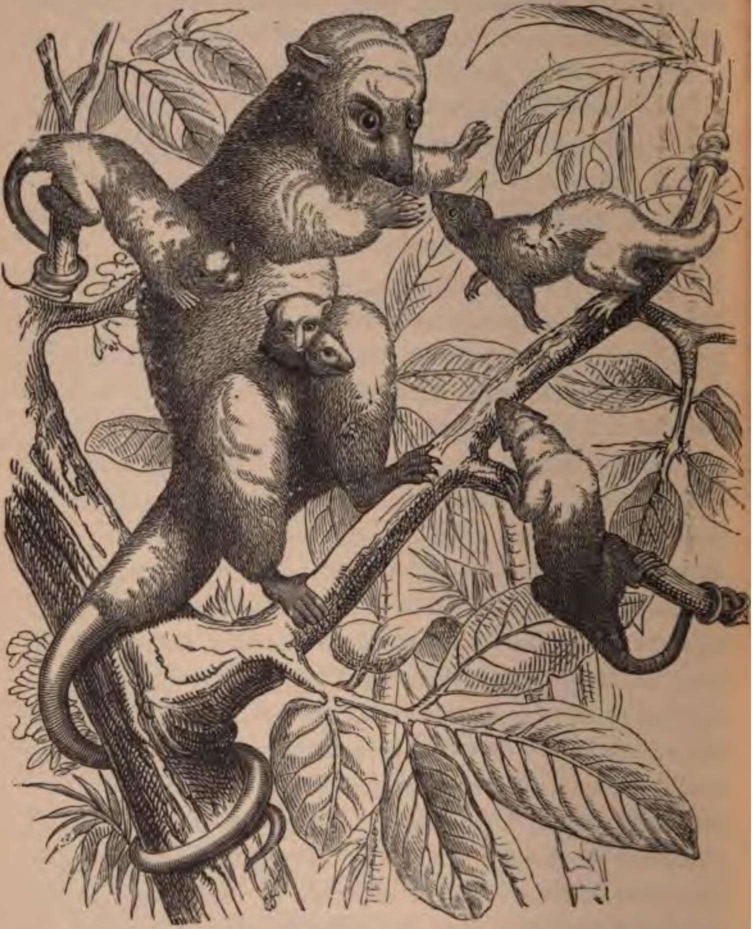


FIG. 197.—The Crab-eating Pouched Rat (*Philander cancrivorus*). A female with two young in its pouch. (After Brehm.)

attains the height of a man, the embryo develops in the uterus but for a month; it is then born in a very incomplete condition, and attains all its further development in the mother's pouch, where, for about nine months, it remains attached to the milk-glands.

All these and other characters (especially the peculiar structure of the internal and external sexual organs of the male and female) clearly show that the whole sub-class of the Pouched Animals (*Marsupialia*) are a single group, which originated from the promammalian branch. From a branch of these Pouched Animals (perhaps from several branches) the parent-forms of the higher Mammals, the Placental Animals, afterwards sprang. Hence we must reckon a whole series of Pouched Animals among the ancestors of the human race; and these constitute the seventeenth stage in the human pedigree.[158]

The remaining stages of our ancestral line, from the eighteenth to the twenty-second, all belong to the group of Placental Animals (*Placentalia*). This very highly developed group of Mammals, the third and last, came into the world at a considerably later period. No single known fossil, belonging to any portion of the Secondary or Mesolithic Epoch, can be referred with certainty to a Placental Animal, while we have plenty of placental fossils dating from every part of the Tertiary or Cænolithic Epoch. From this palæontological fact we may provisionally infer that the third and last main division of Mammals did not develop from the Pouched Animals until the beginning of the Cænolithic Epoch, or, at the earliest, till the close of the Mesolithic Epoch (during the Chalk Period). In our survey of geological formations and periods (pp. 12, 19) we found how comparatively short this whole Tertiary or Cænolithic Epoch was. Judging from the relative thicknesses of the various strata-formations we were able to say that this whole period, during which Placental Animals first appeared, and assumed their respective forms, amounted at most to about three per cent. of the entire duration of the organic history of the earth. (Cf. p. 18.)

All Placental Animals are distinguished from the two lower Mammalian groups already considered, from the Cloacal Animals and Pouched Animals, by many prominent peculiarities. All these characters are present in Man; a most significant fact. For on the most accurate comparative anatomical and ontogenetical researches, we may base the irrefutable proposition that Man is in every respect a true Placental Animal; in him are present all those peculiarities in the structure and in the development of the body which distinguish Placental Animals from the lower Mammalian groups, and at the same time from all other animals. Among these characteristic peculiarities the higher development of the brain, the organ of the mind, is especially prominent. The fore-brain, or large brain (*cerebrum*) is much more highly developed in these than in lower animals. The body (*corpus callosum*), which, like a bridge, connects the two hemispheres of the fore-brain, attains its full development only in Placental Animals; in the Pouched Animals and Cloacal Animals it exists merely as an insignificant rudiment. It is true that in their brain structure the lowest of the Placental Animals yet resemble Pouched Animals very nearly; but within the Placental group we can trace a continuous series of progressive stages in the development of the brain, ascending quite gradually from the lowest stage to the very highly developed mind-organ of the Monkey and of Man. (Cf. Chapter XX.) The human mind is but a more highly developed ape-mind.

The milk-glands of Placental Animals, as of Marsupials, are provided with developed nipples; but the pouch in which the immature young of the latter are carried about and suckled is never present in the former. Nor are the marsupial bones (*ossa marsupialia*) present in Placental Animals; these bones, which are embedded in the abdominal wall, and rest on the anterior edge of the pelvis, are common to Pouched Animals and Cloacal Animals, originating from a partial ossification of the tendons of the inner oblique muscle of the abdomen. It is only in a few beasts of prey that insignificant rudiments of these bones are found. The hook-shaped process of the lower jaw, which characterizes Pouched Animals, is also entirely wanting in Placental Animals.

The character, however, which especially distinguishes Placental Animals, and which has justly given its name to the entire sub-class, is the development of the placenta, or vascular cake. We have already spoken of this organ, in describing the development of the allantois in the human embryo (vol. i. p. 382). The urinary sac or allantois, that peculiar bladder which grows out of the posterior portion of the intestinal canal, is, we found, formed at an early stage in the human embryo just as in the germs of all other Amnion Animals. (Cf. Figs. 132–135, vol. i. p. 377–380.) The thin wall of this sac consists of the same two layers, or skins, as the wall of the intestine itself; internally of the intestinal-glandular layer, and externally of the intestinal-fibrous layer. The cavity of the allantois is filled with fluid; this primitive urine must be chiefly the product of the primitive kidneys. The intestinal fibrous layer of the allantois is traversed by large blood-vessels which accomplish the nutriment and, especially, the respiration of the embryo; these are the navel-vessels, or umbilical vessels (vol. i. p. 400). In all Reptiles and Birds the allantois becomes an immense sac, which encloses the embryo with the amnion, and which does not coalesce with the outer covering of the egg (*chorion*). In Cloacal Animals (*Monotremata*) and Pouched Animals (*Marsupialia*) the allantois is also of this nature. It is only in Placental Animals that the allantois develops into that very peculiar and remarkable formation, called the *placenta*, or "vascular cake." The nature of the placenta is this: the branches of the blood-vessels which traverse the wall of the allantois, penetrate into the hollow tufts of the chorion, which are inserted into corresponding depressions in the mucous membrane of the maternal uterus. As this mucous membrane is also abundantly supplied with blood-vessels, which conduct the mother's blood into the uterus, and as the partition between these maternal blood-vessels and the embryonic vessels in the chorion-tufts soon becomes extremely thin, a direct exchange of substance is soon developed between the two sets of blood-vessels, which is of the utmost importance for the nutrition of the young Mammal. The maternal blood-vessels do not, however, pass directly (anastomosis) into the blood-vessels of the embryonic chorion-tufts, so that the two kinds of blood simply mix, but the partition between the two sets of vessels becomes so thin, that it permits the passage of the most important food-materials, freed from unnecessary matter (transudation, or diosmosis). The larger the embryo grows in Placental Animals, and the longer it remains in the maternal uterus, the more necessary does it become that special structural arrangements should meet the increased consumption of food. In this point there is a very striking difference between the lower and the higher Mammals. In Cloacal Animals and Pouched Animals, in which the embryo remains for a comparatively brief time in the uterus, and is born in a very immature condition, the circulation as it exists in the yelk-sac and in the allantois suffices for nutrition, as in birds and reptiles. In Placental Animals, on the contrary, in which gestation is very protracted, and the embryo remains much longer in the uterus, there attaining its full development within its investing membranes, a new apparatus is required to convey a direct supply of richer nutritive matter; and this is admirably effected by the development of the placenta.

In order rightly to understand and appreciate the formation of this placenta and its important modifications in different Placental Animals, we must once more glance at the external coverings of the mammalian egg. The outermost of these was originally, and during the cleavage of the egg and the first formation of the axial portion of the germ, formed by the so-called *zona pellucida*, and by the thick albuminous covering deposited externally on the latter (Fig. 19, Fig. 21, *z*, *h*, vol. i. p. 178).

We called these two outer coverings, which afterwards amalgamate, the *prochorion*. This prochorion very soon disappears (in man perhaps in the second week of development), and is replaced by the permanent outer egg-membrane, the chorion. The latter, however, is simply the serous membrane, which, as we have already seen, is the product of the outer germ-layer of the germ-membrane vesicle. (See vol. i. p. 401, and Fig. 139, $_4$, $_5$, *sh*, p. 385.) This is at first a very smooth, thin membrane, surrounding the entire egg, as a closed spherical vesicle, and consisting of a single layer of exoderm cells. The chorion, however, becomes very soon studded with a number of little protuberances or tufts (Fig. 139, $_5$, *chz*). These fit themselves into indentations in the mucous membrane of the uterus, and thus secure the egg to the wall of the latter. The tufts are, however, not solid, but hollow, like the fingers of a glove. Like the whole chorion, these hollow tufts consist of a thin layer of cells belonging to the horn-plate. They very soon attain an extraordinary development, growing and branching rapidly. In the spaces between them, new tufts arise in all directions from the serous membrane, and thus before long (in the human embryo in the third week)

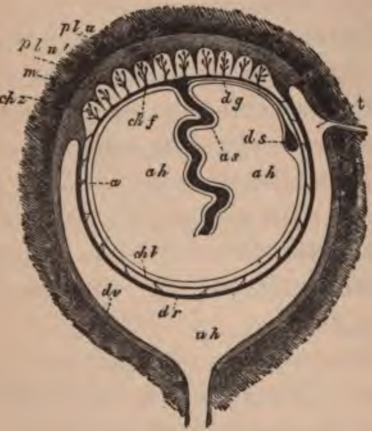


FIG. 198.—Egg-coverings of the human embryo (diagrammatic): *m*, the thick fleshy wall of the uterus; *plu*, placenta, the inner stratum (*plu'*) of which has extended processes between the chorion-tufts (*chz*) (*chf*, tufted, *chl*, smooth chorion); *a*, amnion; *ah*, amnion cavity; *as*, amnion sheath of the navel-cord (passing down into the navel of the embryo, which is not represented here); *dg*, yelk-duct; *ds*, yelk-sac; *dv*, *dr*, decidua (*dv*, true, *dr*, false). The uterus-cavity (*uh*) opens below into the vagina, above, on the right hand side, into an oviduct (*t*). (After Kölliker.)

the whole outer surface of the egg is covered with a dense forest of tufts (Fig. 134).

These hollow tufts are now penetrated from within by the branching blood-vessels, which originate from the intestinal fibrous layer of the allantois, and which contain the blood of the embryo, introduced through the navel vessels (Fig. 198, *chz*). On the other hand, dense networks of blood-vessels develop in the mucous membrane, which lines the inner surface of the uterus, particularly in the neighbourhood of the depressions into which the chorion-tufts penetrate (*plu*). These vascular networks receive the blood of the mother introduced through the uterus vessels. The whole mass of these two sets of vessels, which are here most intimately connected, together with the connecting and enveloping tissues, is called the placenta, or "vascular cake." Properly speaking, the placenta consists of two quite different, though closely connected, parts; internally, of the embryonic placenta (*placenta fœtalis*, Fig. 198, *chz*), and externally of the maternal placenta (*placenta uterina*, Fig. 198, *plu*). The latter is formed by the uterine mucous membrane and its blood vessels: the former by the secondary chorion and the navel vessels of the embryo.

The mode in which these two "vascular cakes" combine to form the placenta, as well as the structure, form, and size of the latter, differs much in different Placental Animals, and affords valuable data for natural classification, and hence also for the tribal history of the whole sub-class. The latter is primarily divisible into two main divisions, based on these differences: the lower Placental Animals, which are called *Indecidua*, and the higher Placental Animals, or *Deciduata*.

To the Indecidua, or lower Placental Animals, belong two very comprehensive and important vertebrate groups: (1) the Hoofed Animals (*Ungulata*)—the Tapirs, Horses, Swine, Ruminants, and others; (2) the Whale-like animals (*Cetomorpha*)—the Sea-cows, Porpoises, Dolphins, Whales, and others. In all these Indecidua the chorion tufts are distributed, singly or in bunches, over the entire surface of the chorion, or over the greater part of it. They are but very loosely attached to the mucous membrane of the uterus, so that the entire outer egg-membrane with its tufts might easily and without using force be drawn out of the depressions in the uterine mucous membrane, just as the hand is withdrawn from a glove. The two "vascular cakes" do not really coalesce at any point of their contact. Hence, at birth the "embryonic cake" (*placenta fœtalis*) is alone removed; the "maternal cake" (*placenta uterina*) is not displaced. The entire mucous membrane of the gravid uterus is but little altered, and, at parturition, suffers no direct loss of substance.

The structure of the placenta in the second and higher division of Placental Animals, the Deciduata, is very different. To this comprehensive and very highly developed mammalian group belong all Beasts of Prey and all Insect-eaters, Gnawers (*Rodentia*), Elephants, Bats, Semi-apes, and, lastly, Apes and Man. In all these Deciduata the whole surface of the chorion is also at first thickly covered with tufts. These, however, afterwards disappear from part of the surface, while they develop all the more vigorously in the remainder. The smooth chorion (*chorion læve,* Fig. 198, *chl*) thus becomes distinct from the tufted chorion (*chorion frondosum,* Fig. 198, *chf*). On the former there are only minute and scattered tufts, or none at all; while the latter is thickly overgrown with highly developed and large tufts. In the Deciduata the tufted chorion alone forms the placenta.

Yet more characteristic of the Deciduata is the very peculiar and intimate connection which is developed in these between the tufted chorion and the contiguous portion of the uterine mucous membrane, and which must be regarded as a true coalescence. The vascular tufts of the chorion push their branches into the sanguineous tissue of this mucous membrane in such a way, and the two sets of vessels are in such close contact and are so interlaced, that the embryonic placenta is no longer distinguishable from the maternal placenta; the two form one whole—a compact and apparently simple placenta. Owing to this intimate coalescence, a portion of the uterine mucous membrane of the mother comes away, at birth, with the firmly adherent egg-membrane. The portion of the mother's body which is thus removed in parturition is called, on account of its separable nature, the deciduous membrane (*decidua*). All Placental Animals which possess this deciduous membrane are classed together as Deciduata. The removal of this membrane at parturition, of course, causes a greater or less loss of blood by the mother, which does not occur in the Indecidua. In the Deciduata, moreover, the lost portion of the uterine mucous membrane must be replaced, after parturition, by a renewal of the tissue.

The structure of the placenta and deciduous membrane is, however, by no means identical throughout the comprehensive group of Deciduata. On the contrary, there are many important differences in this respect, which are in some degree connected with other important structural characters (*e.g.*, the structure of the brain, of the teeth, of the feet), and which may justly, therefore, be turned to account in the phylogenetic classification of Placentals. In the first place, two great groups of Deciduata may be distinguished according to the form of the placenta: in the one group it is ring-shaped or girdle-shaped; in the other it is discoid or cake-shaped. In Deciduata with girdle-shaped placenta (*Zonoplacentalia*) the poles of the oval egg take no part in the formation of the placenta. The "vascular cake" resembles a broad ring-like girdle, embracing the central zone of the egg. It is so in Beasts of Prey (*Carnassia*), both in the terrestrial forms (*Carnivora*) and in the marine forms (*Pinnipedia*). A similar girdle-shaped placenta is found in the False-hoofed Animals (*Chelophora*): the elephants, and Klip Das (Hyrax) with its allies, which were formerly classed as Hoofed Animals. All these Zonoplacentalia belong to one or more side-branches of the Deciduata, which are not nearly allied to Man.

The second and most highly developed group is formed by the Deciduata with discoidal placenta (*Discoplacentalia*). The formation of the placenta is here most localized and its structure most fully developed. The placenta forms a thick, spongy cake, usually in the form of a circular or oval disc, and attached only to one side of the uterine wall. The greater part of the embryonic egg-membrane is, therefore, smooth, without developed tufts. To the Discoplacentalia belong the Semi-apes and Insect-eaters, the Diggers (Effodienta) and the Sloths, Rodents and Bats, Apes and Man. Comparative Anatomy enables us to infer that of these various orders the Semi-apes are the parent-group from which all other Discoplacentals, and perhaps even all Deciduous Animals, have developed as divergent branches. (Cf. Tables XXIII. and XXIV.)

The Semi-apes (*Prosimiæ*) are now represented only by very few forms. These, however, are very interesting, and must be regarded as the last remnants of a group once rich in forms. This group is certainly very ancient, and was probably very prominent during the Eocene Epoch. Their present degraded descendants are scattered widely over the southern portion of the Old World. Most of the species inhabit Madagascar; a few the Sunda Islands; a few others the continents of Asia and Africa. No living or fossil Semi-apes have, as yet, been found in Europe, America, or Australia.[159] The widely scattered posterity of the Semi-apes is considerably diversified. Some forms seem nearly allied to the Marsupials, especially to the Pouched-rats. Others (*Macrotarsi*) are very near akin to the Insect-eaters, and yet others (*Cheiromys*) to the Gnawers (*Rodentia*). One genus (*Galeopithecus*) forms a direct transition to the Bats. Finally, some of the Semi-apes (*Brachytarsi*) approach very near to true Apes. Among the latter are some tail-less forms (*e.g.*, the Lori, *Stenops*, Fig. 199). From these highly interesting and important relations of the Semi-apes to the various Discoplacental orders, we may fairly infer that of the extant representatives of this group, they are the nearest to the common primitive parent-form. Among the direct common ancestors of Apes and Men, there must have been some Deciduata which we should class among the Semi-apes, were we to see them alive. We may therefore consider this order as a special stage, following the Pouched Animals, as the eighteenth stage in the human pedigree.

Probably our ancestors among the Semi-apes closely resembled the extant Brachytarsi or Lemurs (*Lemur, Lichanotus, Stenops*), and, like these, led a quiet life, climbing on trees. The extant Semi-apes are mostly nocturnal animals of gentle and melancholy disposition, subsisting on fruits.

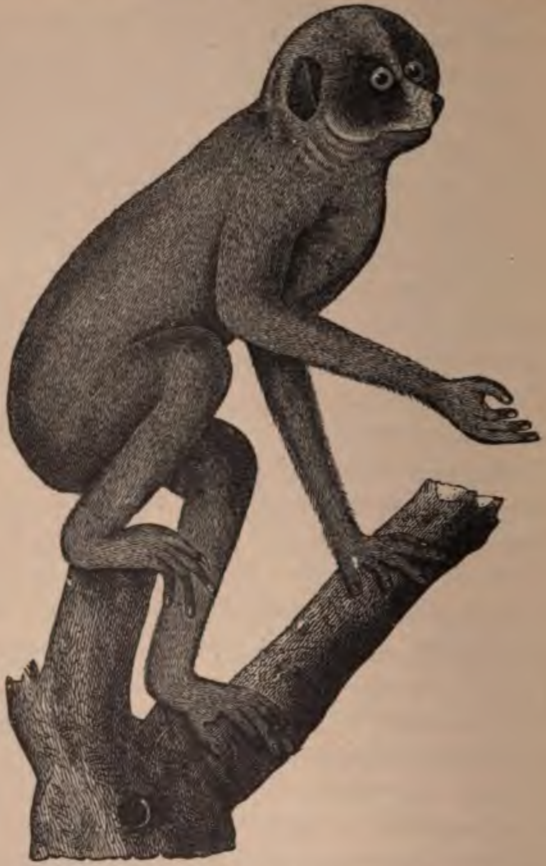


FIG. 199.—The Slender Lori of Ceylon (*Stenops gracilis*).

The Semi-apes are immediately followed by the true Apes (*Simiæ*), as the nineteenth stage in the human pedigree. It has long been beyond doubt that of all animals the Apes are in all respects the most nearly allied to Man. Just as, on the one side, the lowest Apes approach very near to the Semi-apes, so, on the other side, do the highest Apes most closely resemble Man. By carefully studying the Comparative Anatomy of Apes and Man, it is possible to trace a gradual, uninterrupted advance in the Ape-organization up to the purely human structure; and on impartially testing this "Ape-question," which has lately been agitated with such passionate interest, we shall infallibly have to acknowledge the important fact, which was first explicitly laid down by Huxley, that "whatever system of organs be studied, the comparison of their modifications in the ape series leads to one and the same result—that the structural differences which separate Man from the Gorilla and Chimpanzee are not so great as those which separate the Gorilla from the lower Apes." In phylogenetic language this pregnant law established in so masterly a manner by Huxley, is equivalent to the popular phrase: Man is descended from the Ape.

In order to become convinced of the truth of this law, let us now once more consider the placenta and deciduous membrane, on the varied structure of which we justly laid special stress. Men and Apes, in the structure of their disc-shaped placenta and in their decidua, do, indeed, coincide on the whole with all other Discoplacental Animals. But in the more delicate structure of these parts Man is distinguished by peculiarities which he shares only with Apes, and which are absent in other Deciduata. Thus in Man and in the Apes three distinct parts are recognized in the deciduous membrane; these parts may be called the outer, the inner, and the placental deciduous membrane. The outer or true membrane (*d. externa* or *vera*, Fig. 198, *dv*, Fig. 200, *g*), is that portion of the uterine mucous membrane which coats the internal surface of the uterus wherever the latter is not attached to the placenta. The placental or spongy deciduous membrane (*d. placentalis* or *serotina*, Fig. 198, *plu*, Fig. 200, *d*) is simply the maternal placenta

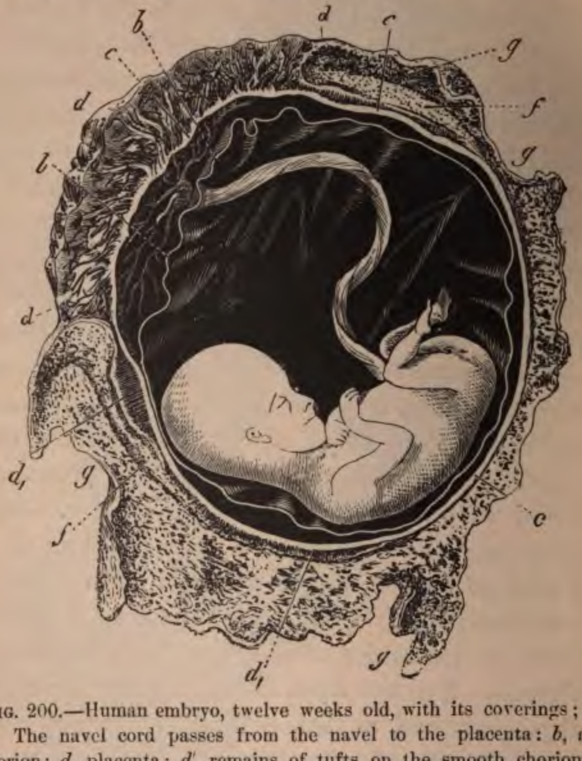


FIG. 200.—Human embryo, twelve weeks old, with its coverings; natural size. The navel cord passes from the navel to the placenta: *b*, amnion; *c*, chorion; *d*, placenta; *d'*, remains of tufts on the smooth chorion; *f*, *decidua reflexa* (inner); *g*, *decidua vera* (outer). (After Bernhard Schultze.)

itself, or the maternal part of the "vascular cake" (*placenta uterina*), *i.e.*, that part of the uterine mucous membrane which coalesces intimately with the chorion-tufts of the embryonic placenta (*placenta fœtalis*). Lastly, the inner or false deciduous membrane (*d. interna* or *reflexa*, Fig. 198, *dr*, Fig. 200, *f*) is that portion of the uterine mucous membrane which, as a peculiar thin envelope, covers all the rest of the egg-surface, lying immediately over the tuftless smooth chorion (*chorion læve*). The origin of these three distinct deciduous membranes, concerning which erroneous notions have been entertained (still retained in the nomenclature), is plain enough; the external or true deciduous

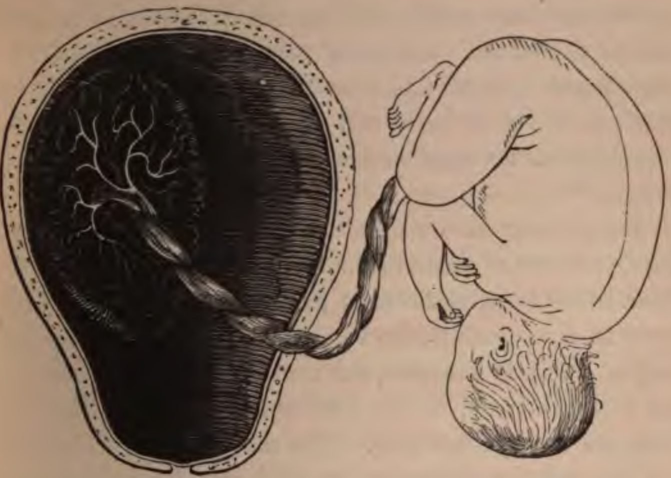


FIG. 201.—Mature human embryo (at the end of pregnancy), in its natural position, taken out of the uterus. On the inner surface of the latter (on the left) is the placenta, which is attached to the navel of the child by the navel cord. (After Bernhard Schultze.)

membrane is a peculiar modification, afterwards lost, of the superficial layer of the original mucous membrane of the uterus. The placental membrane is that portion of the preceding which is completely modified by the intrusion of the chorion-tufts and is employed in forming the placenta. Lastly, the inner deciduous membrane is formed by a ring-shaped fold of the mucous membrane (at the point of union of the *d. vera* and the *d. serotina*) which rises, grows round the egg, and closes in the same way as the amnion.[160]

The peculiar anatomical characters which mark the human egg-membrane re-occur, in the same form, only in Apes. All other Discoplacental Animals present greater or less differences in these points, the conditions being generally more simple. This is the case, for instance, in the structure of the placenta itself, in the coalescence of the chorion tufts with the *decidua serotina*. The matured human placenta is a circular (rarely oval) disc of a soft, spongy character, 6 to 8 inches in diameter, about 1 inch thick, and weighing from 1 to 1½ lb. Its convex, external surface (that which coalesces with the uterus) is very uneven, and tufted. Its internal, concave surface (that which is turned towards the cavity of the egg) is quite smooth, and clothed by the amnion (Fig. 198, *a*). From near the centre of the placenta springs the navel cord (*funiculus umbilicalis*), the development of which we have already observed (vol. i. p. 383). It also is coated by the amnion as with a sheath, which at the navel end passes directly into the abdominal skin (Fig. 200, 201). The mature navel cord is a cylindrical cord, coiled spirally around its axis, and usually about 20 inches long and ½ inch thick. It consists of gelatinous connective tissues ("Wharton's jelly"), in which are contained the remnants of the yelk-vessels and of the great navel vessels; the two navel arteries which convey the blood of the embryo to the placenta, and the great navel vein which brings back the blood from the latter to the heart. The numerous fine branches of these embryonic navel vessels pass into the branched chorion tufts of the fœtal placenta, and with these, finally, grow, in a very peculiar way, into large blood-filled cavities, which spread themselves in the uterine placenta and contain blood from the mother. The anatomical relations, very complex and difficult to comprehend, which are developed between the embryonic and the maternal placenta, exist in this form only in Man and in the higher Apes, while in all other Deciduous Animals their form is more or less different. The navel cord, also, is proportionately longer in Man and in Apes than in other Mammals.

As in these important characters, so also in every other morphological respect, Man appears as a member of the order of Apes, and cannot be separated from the latter. The great originator of systematic description of nature, Karl Linnæus, with prophetic penetration, united Men, Apes, Semi-apes, and Bats in a single natural division, under the name of Primates, that is, the first, the lords of the animal kingdom. Later naturalists dissolved this order of Primates. The Gŏttingen anatomist, Blumenbach, first placed Man in a special order, which he called that of Two-handed Animals (*Bimana*); in a second order, he united Apes and Semi-apes under the name of Four-handed Animals (*Quadrumana*), while a third order included the distantly related Bats (*Chiroptera*). The separation of the Bimana and Quadrumana was retained by Cuvier and most succeeding zoologists. It seems very important, but is really wholly unjustifiable. This was first shown in the year 1863 by Huxley. Supported by very accurate Comparative Anatomical researches, he proved that Apes are as "two-handed" as Men, or, conversely, that Men are as "four-handed" as Apes. Huxley showed, with convincing clearness, that the ideas previously held of the hand and the foot were false, and were incorrectly founded on physiological instead of on morphological distinctions. The circumstance that in the hand, the thumb may be opposed to the other four fingers, thus permitting the act of grasping, appeared especially to distinguish the hand from the foot, in which the corresponding great toe cannot be thus opposed to the four remaining toes. Apes, on the contrary, can grasp in this way with the hind-foot as well as with the fore-foot, and were therefore regarded as four-handed. Many tribes, however, among the lower races of men, especially many negro tribes, use the foot in the same way as the hand. In consequence of early habit and continued practice, they are able to grasp as well with the foot as with the hand (for example, in climbing, they grasp the branches of trees). Even new-born children of our own race have a very strong grasping power in the great toe, with which they can hold a spoon as fast as with the hand. The physiological distinction between hand and foot can, therefore, neither be strictly carried out, nor scientifically established. Morphological characters must be used for this purpose.

A sharp morphological distinction of this kind—that is, one founded on anatomical structure—between hand and foot, between the anterior and the posterior limbs, is actually possible. There are essential and permanent differences both in the structure of the bony skeleton and in that of the muscles which are attached to the hand and the foot; and these are exactly the same in Man and in the Ape. There is, for instance, an essential difference in the arrangement and number of the wrist-bones of the hand (*carpus*) and the ankle-bones of the foot (*tarsus*). The muscle-masses present equally constant differences. The posterior extremity, the foot, has always three muscles (a short flexor muscle, a short extensor muscle, and a long muscle attached to the muscles of the tibia) which are never present in the anterior extremity, the hand. The disposition of the muscles is also very different in the two sets of limbs. These characteristic differences between the anterior and the posterior extremities occur in Man just as in Apes. There can, therefore, be no doubt, that the foot of the Ape deserves the name as truly as that of the Man; and that all true Apes are as genuinely two-handed animals (*Bimana*) as Man. Thus the usual distinction of the Apes as Quadrumana is wholly unjustifiable.

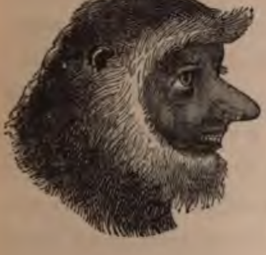
It might now be asked whether, quite apart from these, there are not other marks by which Man is more widely separated from the Apes than are the different species of Apes from each other. Huxley has given a final negative to this question so convincingly, that the opposition now raised against him in many quarters must be regarded as completely unfounded and ineffective. Based on an accurate study of the Comparative Anatomy of all parts of the body, Huxley brought forward very significant proof that, in every anatomical respect, the differences between the highest and the lowest Apes are greater than the corresponding differences between the highest Apes and Man. He therefore restored Linnæus's order of Primates (excluding the Bats), and divided it into three different sub-orders, the first of which is formed by the Semi-apes (*Lemurida*), the second by the true Apes (*Simiadæ*), and the third by Men (*Anthropidæ*).[161]

Yet, if we proceed logically and without prejudice, in accordance with the principles of scientific reasoning, we find, on the basis of Huxley's own law, this division inadequate, and must go considerably further. As I first showed in 1866, in treating this question in my *Generelle Morphologie*, we are fully justified in taking at least one important step further, in assigning to Man his natural place in one of the divisions of the Ape-order. All the characters distinctive of this one division of the Apes are present in Man, while they are absent in other Apes. We are, therefore, not justified in forming a distinct order for Man apart from the true Apes.

The order of the true Apes (*Simiæ*), the Semi-apes being excluded, has long been divided into two natural main groups, which, among other points, are distinguished by their geographical distribution. Those of one division (*Hesperopitheci*, or Western Apes) live in the New World, in America. The other division, to which Man belongs, is that of the *Heopitheci*, or Eastern Apes; these live in the Old World, in Asia, Africa, and, formerly, in Europe. All the Apes of the Old World, all Heopitheci, share, in common with Man, all those characteristics to which special prominence is justly given, in distinguishing these two groups of Apes, in zoological classification; among these characteristics the structure of the teeth is most prominent. The objection is at once evident that the teeth are, in a physiological sense, much too subordinate a part of the body to justify so great a weight being attached to their structure in so important a question. There are, however, good reasons for this prominent consideration of the structure of the teeth; and it is with perfect correctness and propriety that systematic zoologists have, for more than a century, given special weight to this character in systematically distinguishing and arranging the mammalian orders. The number, form, and disposition of the teeth are transmitted much more accurately within the respective orders of the mammals than are most other zoological characteristics. The structure of the human teeth is well known. In maturity there are 32 teeth in our jaws, and of these 32 teeth, 8 are front-teeth, 4 canine-teeth, and 20 molar-teeth. The eight front-teeth or incisors (*dentes incisivi*), which are situated in the centre of the jaws, exhibit characteristic differences in the upper and lower jaw. In the upper the inner incisors are larger than the outer; in the lower jaw, on the contrary, the inner incisors are smaller than the outer. Next to these, on each side, both in the upper and lower jaw, is a corner-tooth, which is larger than the incisors, the so-called eye-tooth, or canine (*dens caninus*). Sometimes this tooth becomes very prominent in Men, as in most Apes and many other Mammals, and forms a sort of tusk. Finally, next to this, on each side, and in each jaw, are situated five back-teeth, or molar-teeth (*dentes molares*), of which the two foremost (the bicuspid teeth) are small, have but a single fang, and are subject to the change of teeth, while the three hinder molars are much larger, have two fangs, and do not appear till after the temporary teeth have been shed (so-called "grinders"). The Apes of the

Old World have exactly this human structure of the teeth,—all Apes which have as yet been found, either living or as fossils, in Africa, Asia, and Europe. All Apes of the New World, on the contrary, all American Apes, have an extra tooth on both sides of each jaw; this is a biscupid tooth. Thus they have six back-teeth on both sides of each jaw,—in all, thirty-six teeth. This characteristic difference between the Eastern and Western Apes has been so constantly transmitted within the two groups, that it is of the greatest value to us. A small family of South American Apes does, indeed, appear to form an exception in this respect. The pretty little Silk Apes, or Marmosets (*Hapalida*), namely, to which the Brush-monkey (*Midas*) and the tufted Marmoset (*Jacchus*) belong, have but five back-teeth in each half of the jaw, instead of six, and, accordingly, seem to approach nearer the Eastern Apes. But on closer observation it is found that, like all the Western Apes, they have the three biscupids, and that the hindmost grinder has been lost. Thus this apparent exception confirms the value of the distinction.

Among the other marks by which the two main groups of the Apes are distinguished, the structure of the nose is specially important and prominent. In all Old World Apes the structure of the nose is the same as in Man; namely, a comparatively narrow partition of the two halves, so that the nostrils are directed downwards. In a few Eastern Apes, the nose projects as prominently and is as characteristically formed as in Man. We have already called attention, in this respect, to the remarkable Nose-ape (*Semnopithecus nasicus*), which has a well-curved and long nose (Fig. 202). Most of the Eastern Apes have, it is true, a somewhat flatter nose, as, for instance, has the white-nosed Sea-cat (*Cercopithecus petaurista*, Fig. 203); yet in all the partition of the nose is narrow and thin. On the contrary, all American Apes have a different nasal structure. In them, the partition is peculiarly broadened and thickened below, and the wings of the nose are not developed, in consequence of which the nostrils are not below, but are turned outwards. This characteristic difference in the structure of the nose has also been so accurately transmitted in both groups, that, on account of it, the Apes of the New World have been called Flat-nosed (*Platyrhinæ*), and those of the Old World Narrow-nosed (*Catarhinæ*). The former are, on the average, inferior in organization.



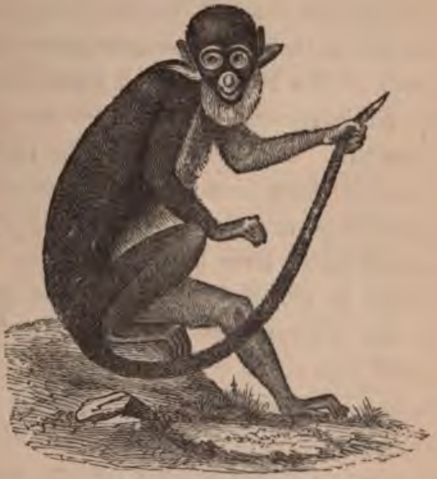


FIG. 202.—Head of Nose-ape (*Semnopithecus nasicus*).
FIG. 203.—The white-nosed Sea-cat (*Cercopithecus petaurista*).

The division of the order of Apes into two sub-orders, the *Platyrhinæ* and the *Catarhinæ*, is, on account of the constant hereditary characters, now generally accepted by zoologists, and receives much support from the geographical distribution of the two groups between the New and Old Worlds. From this follows the direct inference, very important in its bearing on the Phylogeny of Apes, that, from the primæval common parent-form of the Ape-order, two diverging lines branched out at a very early period, one of which spread over the New World, the other over the Old. It is certain that all the Flat-nosed Apes, on the one hand, are descendants of a common parent-form, and, on the other hand, all the Narrow-nosed Apes from another

An inference concerning our own pedigree may be drawn from this. Man has exactly the same characters, the same peculiar formation of the teeth and nose, as all the Catarhinæ, and is as thoroughly distinguished by these charateristics from the Platyrhinæ. We are therefore compelled, in classifying the Primates, to assign to Man a place in the Narrow-nosed group. The bearing of this on our tribal history is, that Man is immediately related in blood to the apes of the Old World, and may be traced from a parent-form common to all other Catarhinæ also. Man is a genuine Narrow-nosed Ape in his whole structure and in origin, and has descended from some unknown, extinct Catarhine form in the Old World. On the other hand, the Apes of the New World, the Flat-nosed group, constitute a diverging branch of our family tree, and stand in no near genealogical relation to the human race.

We have now reduced the circle of our nearest allies to the small group, containing comparatively few forms, which is represented by the sub-order of the Narrow-nosed, or Eastern Apes. Finally, the question which now remains to be answered is—what position in this sub-order must be assigned to Man, and whether other inferences as to the structure of our immediate ancestors may be drawn from this position. The comprehensive and acute researches into the Comparative Anatomy of Man and the various Catarhinæ, which Huxley has recorded in his work on the "Evidence as to Man's Place in Nature," are of the greatest value in furnishing the answer to these important questions. The inevitable conclusion is, that the difference between Man and the highest Narrow-nosed Apes (the Gorilla, Chimpanzee, Orang) is slighter in every respect than the corresponding differences between the highest and the lowest Catarhines (the Sea-cat, Macaque, Baboon). Even within the small group of the Tail-less man-like Apes (*Anthropoides*) the several genera do not differ less from each other than they do from Men. This is seen by a glance at the skeletons represented here, as arranged by Huxley (Figs. 204–208). If the skull, or the vertebral column, together with the rib-system, or the anterior or posterior members, are compared; or if the comparison is extended to the muscular system, the circulatory system, the brain, etc., a candid and unprejudiced examination always results in the same conclusion, that Man does not differ more from the higher Catarhines than the extreme forms of the latter (for example, the Gorilla and Baboon) differ from each other. We can, therefore, complete the important proposition already quoted from Huxley: We may take whatever system of organs we will,—the comparison of their modifications within the ranks of the Catarhinæ leads us

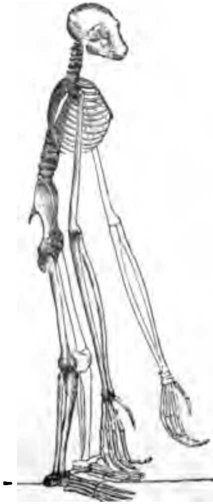


Fig. 204.
(Cf. p. 181.)
Gibbon.

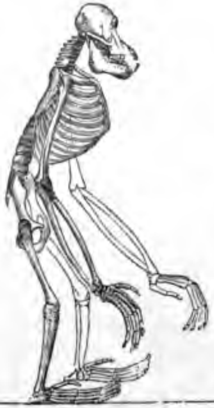


Fig. 205.
(Plate XIV. Fig. 3.)
Orang-outang.

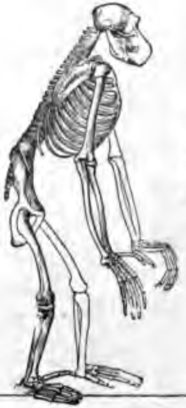


Fig. 206.
(Plate XIV. Fig. 1.)
Chimpanzee.

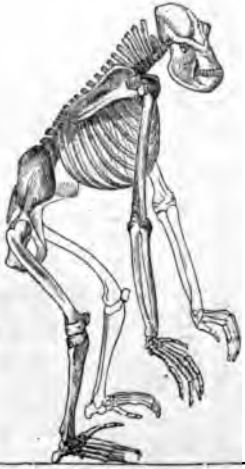


Fig. 207.
(Plate XIV. Fig. 2.)
Gorilla.

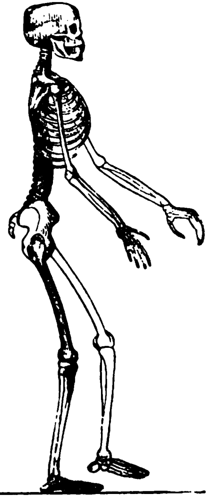


Fig. 208.
(Plate XIV. Fig. 4.)
Man.

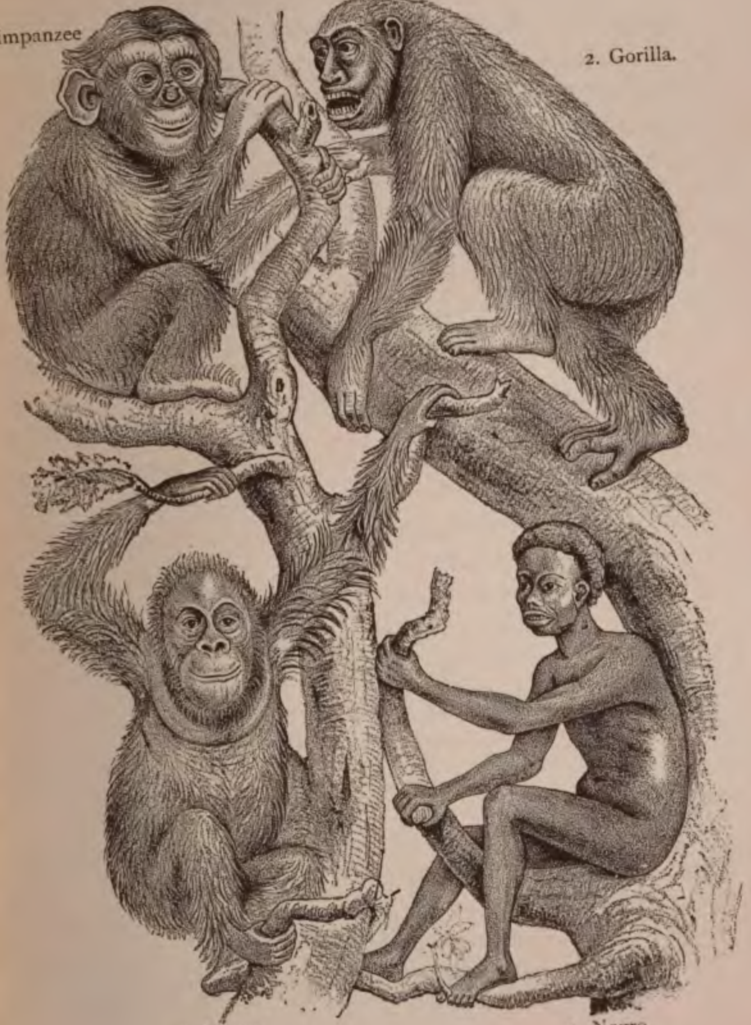
to one and the same conclusion: that the anatomical differences that distinguish Man from the most highly developed Catarhinæ (the Orang, Gorilla, Chimpanzee), are not so great as those which separate the latter from the lowest Catarhinæ (Sea-cat, Macaque, Baboon).

We must, therefore, consider the proof complete, that Man is descended from other Narrow-nosed Apes (*Catarhinæ*). Although future researches into the Comparative Anatomy and Ontogeny of the existing Catarhines, as well as of their fossil relatives, promise us various new details, yet no future discovery can ever overthrow that important proposition. Our Catarhine ancestors must, of course, have passed through a long series of varied forms, before Man finally developed as the most perfect form. The following must be considered as the most important advances by which this "Creation of Man," his differentiation from the most nearly allied Catarhine Apes, was effected: Habituation to upright carriage and, in connection with this, the greater differentiation of the anterior and posterior limbs; also, the development of articulate speech and its organ, the larynx; and lastly, and especially, the more perfect development of the brain and its function, the soul; sexual selection must have exerted an extraordinarily important influence, as Darwin has conclusively proved in his celebrated work on sexual selection.[162]

With reference to these advances, we may, among our Catarhine ancestors, distinguish at least four important ancestral stages, marking prominent epochs in the great historical process of the origin of Man. As the nineteenth stage in the human pedigree, next to the Semi-apes, we may place the oldest and lowest Catarhine Apes, which developed from the former by the formation of the characteristic catarhine head, and by the peculiar modification of the teeth, the nose, and the brain. This oldest parent-form of the whole Catarhine group must, certainly, have been thickly covered with hair, and must have had a long tail; was, in fact, a Tailed Ape (*Menocerca*, Fig. 203). They were already in existence during the earlier part of the Tertiary Epoch (during the Eocene Period), as is shown by fossil remains of Eocene Catarhines. Among extant Tailed Apes, the Slender Apes (*Semnopitheci*) are perhaps most nearly related to this parent-form.[163]

As the twentieth stage in the human pedigree, next to these Tailed Apes, we must rank the Tail-less man-like Apes (*Anthropoides*), under which name the most highly developed Catarhines, those most nearly related to Man, have been grouped. They originated from the Tailed Catarhines, by the loss of the tail, the partial loss of their hairy covering, and the further development of the brain, the latter being indicated in the preponderating development of the brain-skull over the facial skull. At the present time but few forms of this remarkable family are in existence; they are distributed into two different groups, an African and an Asiatic group. The African Man-like Apes are limited to the western part of tropical Africa, but are probably distributed over Central Africa in several species. Only two species are well known: the Gorilla (*Pongo gorilla*, or *Gorilla engina*), the largest of all Apes (Fig. 207); and the smaller Chimpanzee (*Pongo troglodytes*, or *Engeco troglodytes*), which may be seen in several zoological gardens (Figs. 206, Plate XIV. Figs. 1, 2). Both the African Man-like Apes are black in colour, and like their countrymen,

PLATE XIV.


Chimpanzee
2. Gorilla.
3. Orang.
4. Negro.

the Negroes, have the head long from back to front (dolichocephalic). The Asiatic Man-like Apes are, on the contrary, mostly of a brown, or yellowish brown colour, and have the head short from back to front (brachycephalic), like their countrymen, the Malays and Mongols. The largest Asiatic Man-like Ape is the well-known Orang, or Orang-outang (Fig. 128), which is indigenous in the Sunda Islands (Borneo, Sumatra), and is brown in colour. Two species have recently been distinguished: the great Orang (*Satyrus Orang*; Fig. 205, Plate XIV. Fig. 3), and the small Orang (*Satyrus morio*). A genus of smaller Anthropoids (Fig. 204), the Gibbons (*Hylobates*), live on the main-land of Southern Asia and on the Sunda Islands; from four to eight different species of these have been distinguished. Neither of these living Anthropoids can be indicated as the Ape absolutely most like Man. The Gorilla approaches nearest to Man in the structure of the hand and foot, the Chimpanzee in important structural details in the skull, the Orang in the development of the brain, and the Gibbon in that of the thorax. It is evident that no single one of these existing Man-like Apes is among the direct ancestors of the human race; they are all the last scattered remnants of an old, catarhine branch, once numerous, from which the human race has developed as a special branch and in a special direction.

Although Man (*Homo*) ranks immediately next to this anthropoid family, from which he doubtless directly originated, yet the Ape-men (*Pithecanthropi*) may be inserted here, as an important intermediate form between the two, and as the twenty-first stage in our ancestral series. In the "Natural History of Creation" (vol. ii. p. 293), I have applied this name to the speechless Primitive Men (*Alali*), who made their appearance in what is usually called the human form, that is, having the general structure of Men (especially in the differentiation of the limbs)—but yet being destitute of one of the most important qualities of Man, namely, articulate speech, as well as of the higher mental development connected with speech. The higher differentiation of the larynx and of the brain occasioned by the latter, first gave rise to the true "Man."

Comparative Philology has recently shown that the present human language is polyphyletic in origin, that several, and probably many, different original languages must be recognized, as having developed independently from each other. The history of the development of languages also teaches us (its Ontogeny in every child, as well as its Phylogeny in every race), that the actual rational language of men developed gradually, only after the body had developed into the specific human form. It is even probable that the formation of language did not begin till after the differentiation of the various species, or races of men, and this presumably occurred in the beginning of the Quaternary Epoch, or the Diluvial Period. The Ape-men, or *Alali*, were therefore probably already in existence toward the close of the Tertiary Epoch, during the Pliocene Period, perhaps even as early as the Miocene Period.[164]

Lastly, the genuine or speaking human being (*Homo*) must be considered as the twenty-second and final stage in our animal pedigree. Man originated from the preceding stage in consequence of the gradual improvement of inarticulate animal sounds into true human articulate speech. Only very uncertain conjectures can be formed as to the time and place of this true "Creation of Man." It is probable that Primæval Man originated during the Diluvial Epoch, in the torrid zone of the Old World, either on the continent of tropical Asia or Africa, or on an earlier continent which has now sunk below the surface of the Indian Ocean, and which extended from Eastern Africa (Madagascar and Abyssinia) to Eastern Asia (the Sunda Islands and Eastern India). In my "Natural History of Creation" (Chapter XXIII. and Table XV), I have already fully discussed the important evidence as to the former existence of this large continent, called Lemuria, and how the distribution of the various species and races of men probably took place from this "Paradise" over the surface of the earth. In the same place, I have also fully discussed the inter-relations of the various races and species of the human race.[165]

TABLE XXII.

Systematic Survey of the Periods in the Tribal History of the Human Race.

(Compare Table VIII., vol. i. p. 402.)

FIRST MAIN PERIOD IN TRIBAL HISTORY.

The Plastid Ancestors of Man.

The form of the ancestors of man is equal to the simple individual of the **first** order, **a single plastid.**

First Stage: **Moneron Series** (Fig. 163, p. 46).

The ancestors of man are single, living, **simple cytods.**

Second Stage: **Amœba Series** (Fig. 167 p. 53).

The ancestors of man are single, living, **simple cells.**

SECOND MAIN PERIOD IN TRIBAL HISTORY.

The many-celled Primitive Animal Ancestors of Man.

The ancestors of man consist of a closely-united society of many homogeneous cells; hence their form-value is that of individuals of the **second** order, of **Idorgana.**

Third Stage: **Synamœba Series** (Fig. 170, p. 55).

The ancestors of man are many-celled primitive animals of the simplest kind: solid masses of simple, homogeneous cells.

Fourth Stage: **Planæa Series** (Figs. 172, 173, p. 60).

The ancestors of man are many-celled primitive animals of a character like that of the *Magosphæra* and certain planula-larvæ, of equal rank with the ontogenetic *Blastula* or *Blastosphæra*; hollow spheres, the wall of which consists of a single stratum of ciliated cells.

THIRD MAIN PERIOD IN TRIBAL HISTORY.

The Invertebrate Intestinal Animal Ancestors of Man.

The ancestors of man have the form-value of individuals of the third order, of **inarticulate individuals.** The body encloses an intestinal cavity with a mouth, and consists at first of two primary germ-layers, afterwards of four secondary germ-layers.

Fifth Stage : **Gastræa Series** (Figs. 174–179, p. 65).

The ancestors of man have the form-value and structure of a **Gastrula.** The body consists merely of a simple primitive intestine, the wall of which is formed of the two primary germ-layers.

Sixth Stage : **Chordonium Series** (Figs. 184–188, p. 80–90).

The ancestors of man are **worms** : at first, primitive worms, allied to the *Turbellaria;* afterwards worms of higher rank, *Scolecida;* finally, notochord-animals with the organization of the ascidian larvæ. The body is composed of four secondary germ-layers.

FOURTH MAIN PERIOD IN TRIBAL HISTORY.

The Vertebrate Ancestors of Man.

The ancestors of man are vertebrates, and their form-value is, therefore, that of **an articulated individual,** or **a chain of metamera.** The skin-sensory layer is specialized into the horn-plate, medullary tube, and primitive kidneys. The skin-fibrous layer has divided into the leather-plate, primitive vertebræ (muscular plate and skeleton-plate), and the notochord. From the intestinal-fibrous layer originates the heart with the main blood-vessels and the fleshy intestinal wall. From the intestinal-glandular layer, the epithelium of the intestinal tube is formed. The formation of metamora is constant.

Seventh Stage : **Acrania Series** (Fig. 189 ; Pl. XI. Fig. 15).

The ancestors of man are **skull-less vertebrates,** like the extant **Amphioxus**. The body already forms a chain of metamera, several primitive vertebræ having separated off. The head is not yet entirely distinct from the trunk. The medullary tube has not separated into brain-bladders. The heart is very simple, without chambers. The skull is still wanting; as are also the jaws and limbs.

Eighth Stage: **Monorhina Series** (Fig. 190; Pl. XI. Fig. 16).

The ancestors of man are jaw-less **skulled animals** (resembling the developed **Myxinoides** and **Petromyzontes**). The number of the metamera is increasing. The head is becoming more distinctly differentiated from the trunk. The anterior end of the medullary tube swells into a bladder-like structure and forms the brain, which is soon differentiated into five brain-bladders. At the sides of these appear the three higher organs of sense. The heart is divided into auricle and ventricle. The jaws, limbs, and swimming-bladder are still wanting.

Ninth Stage: **Ichthyoda Series** (Figs. 191, 192; Pl. XII. and XIII.).

The ancestors of man are **fish-like skulled animals**: first, **Primitive Fishes** (*Selachii*), then **mud-fishes** (*Dipneusta*),then **gilled Batrachians** (*Sozura*). The ancestors belonging to this Ichthyoda stage develop two pairs of limbs: a pair of anterior limbs (pectoral fins) and a pair of posterior limbs (ventral fins). The gill-arches are formed between the gill-openings, and from them are formed the first pair of jaw-arches (upper and lower jaws). The swimming-bladder (lungs), liver, and pancreas grow from the intestinal canal.

Tenth Stage: **Amniota Series** (Figs. 195–208; Pl. XIV.).

The ancestors of man are **amnion-animals** or **gill-less vertebrates**: first, **Primitive amniota** (*Protamnia*), then **Primitive mammals** (*Monotrema*); next, **Pouched animals** (*Marsupialia*); then **Semi-apes** (*Prosimiæ*), and, lastly, **Apes** (*Simiæ*). The ape-ancestors of man are first tailed *Catarhini*, then tail-less Catarhini (*Anthropoides*), then speechless Ape-men (*Alali*), and at last genuine, speaking men. The ancestors belonging to this amnionate series develop an amnion and allantois, and gradually acquire the mammalian structure, and at last the specific human form.

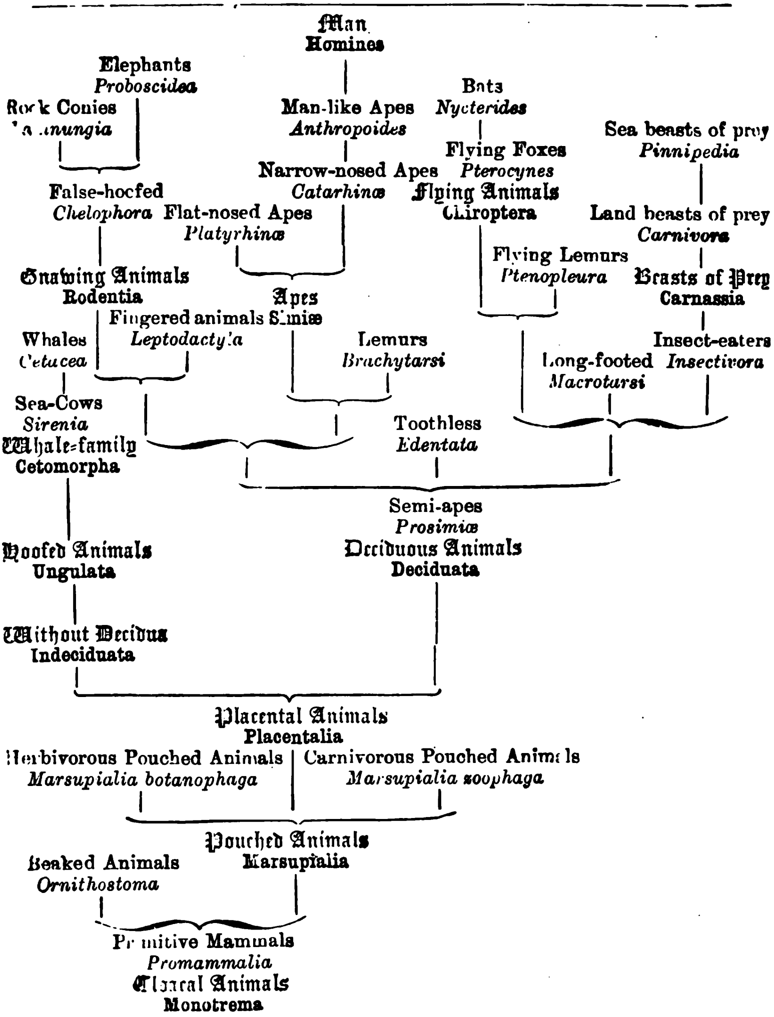
TABLE XXIII.

Systematic Survey of the Phylogenetic Classification of Mammals.

I. First Sub-class of Mammals	Cloacal Animals (*Monotrema*, or *Ornithodelphia*)	1. Primitive Mammals		***Promammalia***
		2. Beaked Animals		***Ornithostoma***
II. Second Sub-class of Mammals	Pouched Animals (*Marsupialia*, or *Didelphia*)	3. Herbivorous Pouched Animals		***Botanophaga***
		4. Carnivorous Pouched Animals		***Zoophaga***
III. Third Sub-class of Mammals: Placental Mammals (*Placentalia*, or *Monodelphia*)	III. (*a*) Placental Mammals without Decidua, with Tufted Placenta *Indecidua* *Villiplacentalia*	5. Hoofed Animals *Ungulata*	Single-hoofed	***Perissodactyla***
			Double-hoofed	***Artiodactyla***
		6. Whale-like Animals *Cetomorpha*	Sea-cows	***Sirenia***
			Whales	***Cetacea***
	III. (*b*) Placental Mammals with Decidua, with Girdle Placenta *Deciduata* *Zonoplacentalia*	7. Pseudo-hoofed Animals *Chelophora*	Rock Conies	***Lamnungia***
			Elephants	***Proboscidea***
		8. Beasts of Prey *Carnassia*	Land Beasts of prey	***Carnivora***
			Marine Beasts of prey	***Pinnipedia***
	III. (*c*) Placental Mammals with Decidua, with Discoid Placenta *Deciduata* *Discoplacentalia*	9. Semi-apes *Prosimiæ*	Fingered animals	***Leptodactyla***
			Long-footed	***Macrotarsi***
			Flying Lemur	***Ptenopleura***
			Lemurs	***Brachytarsi***
		10. Gnawing Animals *Rodentia*	Squirrel species	***Sciuromorpha***
			Mouse species	***Myomorpha***
			Porcupine species	***Hystrichomorpha***
			Hare species	***Lagomorpha***
		11. Toothless *Edentata*	Digging animals	***Effodientia***
			Sloths	***Bradypoda***
		12. Insect-eaters *Insectivora*	With Cœcum	***Menotyphla***
			Without Cœcum	***Lipotyphla***
		13. Flying Animals *Chiroptera*	Flying Foxes	***Pterocynes***
			Bats	***Nycterides***
		14. Apes *Simiæ*	Flat-nosed	***Platyrhinæ***
			Narrow-nosed Apes	***Catarhinæ***

TABLE XXIV.

Pedigree of Mammals.



PEDIGREE OF MAN.

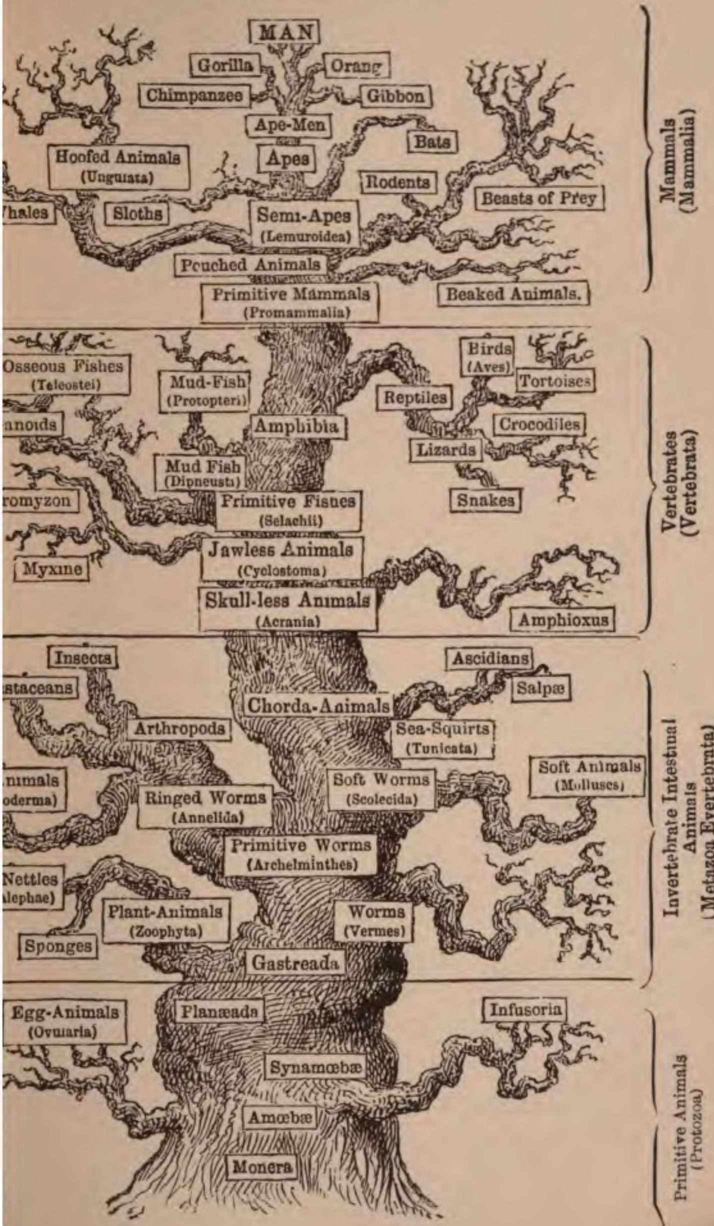


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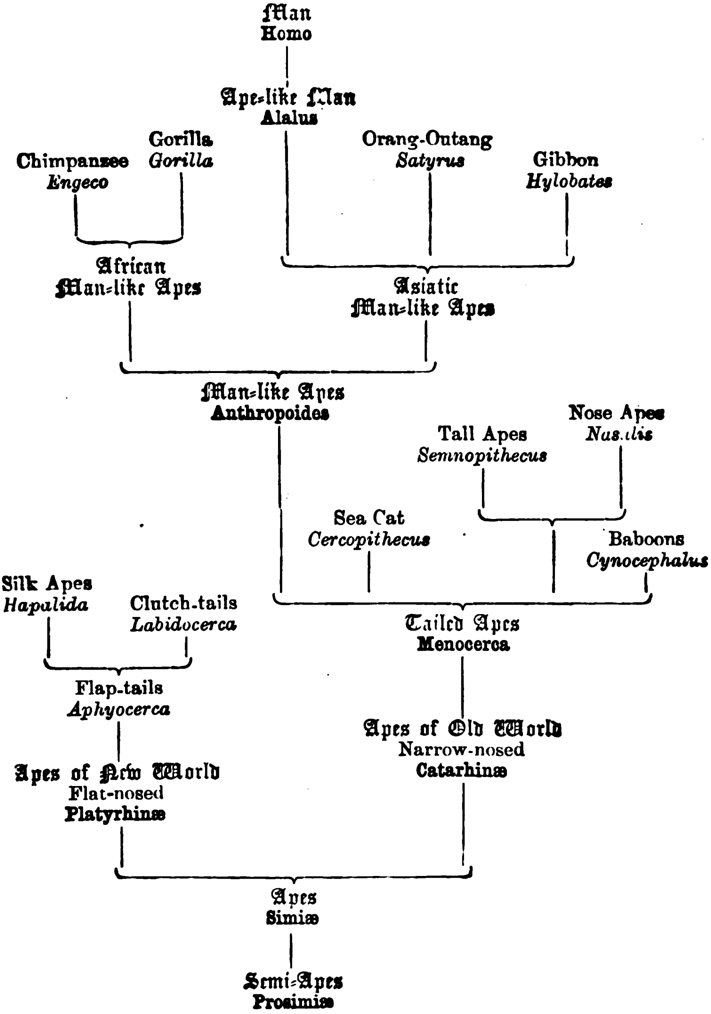
TABLE XXV.

Pedigree of Apes.



CHAPTER XX.

THE HISTORY OF THE EVOLUTION OF THE EPIDERMIS AND THE NERVOUS SYSTEM.

Animal and Vegetative Organ-systems —Original Relations of these to the Two Primary Germ-layers.—Sensory Apparatus.—Constituents of Sensory Apparatus: originally only the Exoderm, or Skin-layer; afterwards, the Skin-covering specialized from the Nerve-system.—Double Function of the Skin (as a Covering and as Organ of Touch).—Outer Skin (*Epidermis*) and Leather-skin (*Corium*).—Appendages of the Epidermis: Skin-glands (Sweat-glands, Tear-glands, Sebaceous Glands, Milk-glands); Nails and Hair.—The Embryonic Wool-covering.—Hair of the Head and of the Beard.—Influence of Sexual Selection.—Arrangement of the Nerve-system.—Motor and Sensory Nerves.—Central Marrow: Brain and Dorsal Marrow.—Constitution of the Human Brain: Large Brain (*Cerebrum*) and Small Brain (*Cerebellum*).—Comparative Anatomy of the Central Marrow.—Germ-history of the Medullary-tube.—Separation of the Medullary-tube into Brain and Dorsal Marrow.—Modification of the Simple Brain-bladder into Five Consecutive Brain-bladders: Fore-brain (Large Brain, or *Cerebrum*), Twixt-brain ("Centre of Sight"), Mid-brain ("Four Bulbs"), Hind-brain (Small Brain, or *Cerebellum*), After-brain (Neck Medulla).—Various Formation of the Five Brain-bladders in the various Vertebrate Classes.—Development of the Conductive Marrow, or "Peripheric Nervous System."

"Hardly any part of the bodily frame, then, could be found better calculated to illustrate the truth that the structural differences between Man and the highest Ape are of less value than those between the highest and the lower Apes, than the hand or the foot, and yet, perhaps, there is one organ which enforces the same conclusion in a still more striking manner—and that is the brain."—*Man's Place in Nature*, p. 94 (1863).

"As if to demonstrate, by a striking example, the impossibility of erecting any cerebral barrier between Man and the Apes, Nature has provided us, in the latter animals, with an almost complete series of gradations, from brains little higher than that of a Rodent to brains little lower than that of Man."—*Ibid.* p. 96.

OUR investigations, up to the present, have shown us how the whole human body has developed from an entirely simple beginning, from a single simple cell. The whole human race, as well as the individual man, owes its origin to a simple cell. The one-celled parent-form of the former is, even yet, reproduced in the one-celled germ-form of the latter. In conclusion, we must glance at the evolutionary history of the separate parts which constitute the human body. In this matter, I must, of course, restrict myself to the most general and important outlines; for a detailed study of the evolutionary history of the separate organs and tissues would occupy too much space, and would demand a greater extent of anatomical knowledge than the generality of my readers are likely to possess. In considering the development of the organs, and of their functions, we will retain the method previously employed, except that we will consider the germ-history and the tribal history of the various parts of the body in common. In the history of the evolution of the human body as a whole we have found that Phylogeny everywhere serves to throw light on the obscure course of Ontogeny, and that the clew afforded by phylogenetic continuity alone enables us to find our way through the labyrinth of ontogenetic facts. We shall experience exactly the same fact in the history of the development of the separate organs; but I shall be compelled to explain the ontogenetic and the phylogenetic origin of the organs simultaneously; for the further we penetrate into the details of organic development, and the more minutely we study the origin of the separate parts, the more clearly do we see how inseparably the evolution of the germ is connected with that of the tribe. The Ontogeny of the organs is intelligible and explicable only through their Phylogeny; just as the germ-history of the entire body (the "person") is rendered intelligible only by the history of the tribe. Each germ-form is determined by a corresponding ancestral form. This is as true of the parts as of the whole.

In endeavouring, with the help of this fundamental law of Biogeny, to obtain a general view of the main features in the development of the separate organs of man, we must, in the first place, consider the animal, and then the vegetative organ-systems of the body. The first main group of organs, the animal organ-systems, is formed by the sensory apparatus, together with the motor apparatus. To the former belong the skin-covering, the nervous system, and the organs of the senses. The motor apparatus consists of the passive organs of movement (the skeleton) and the active organs (the muscles). The second main group of organs, the vegetative organ-system, is formed by the nutritive and the reproductive apparatus. To the nutritive apparatus belongs especially the intestinal canal with all its appendages, together with the vascular and renal systems. The reproductive apparatus includes the various sexual organs (the germ-glands, germ-ducts, organs of copulation, etc.).

In earlier chapters (IX. and X.) it has been stated that the animal organ-systems (the instruments of sensation and of movement) proceed especially from the outer primary germ-layer, from the skin-layer. The vegetative organ-systems, on the other hand (the instruments of nutrition and reproduction), proceed principally from the inner primary germ-layer, from the intestinal layer. This radical contrast between the animal and the vegetative spheres of the body is, it is true, by no means absolute either in man or in the higher animals; on the contrary, many separate parts of the animal apparatus (*e.g.*, the intestinal nerve, or sympathetic) originated from cells which have proceeded from the entoderm; and, on the other hand, a large part of the vegetative apparatus (*e.g.*, the mouth-cavity, and probably the greater part of the urinary and sexual organs) is formed of cells which are originally derived from the exoderm. Moreover, in the bodies of all the more highly developed animals, the most heterogeneous parts are so intermixed and blended that it is often extremely difficult to assign its true source to each one of the constituent parts. But, on the whole, we may assume as a certain and important fact, that in Man, and in all high animals, the greater part of the animal organs must be referred to the skin-layer, or exoderm; the greater part of the vegetative organs to the intestinal layer, or entoderm. For this reason, Baer called the former the animal germ-layer, the latter, the vegetative germ-layer (Cf. vol. i. pp. 53 and 196). Of course, in making this important assumption, we pre-suppose the correctness of Baer's view, according to which the skin-fibrous layer (the "flesh stratum" of Baer) must have originated (phylogenetically) from the exoderm, and, on the other hand, the intestinal-fibrous layer (Baer's "vascular layer") from the entoderm.

This influential view, which is yet much disputed, is, we

TABLE XXVI.

Systematic Survey of the Organ-Systems of the Human Body.

(N.B.—The origin of the separate organs from the four secondary germ-layers is indicated by the Roman numerals (I.–IV.): I. Skin-sensory layer; II. Skin-fibrous layer; III. Intestinal-fibrous layer; IV. Intestinal-glandular layer.)

ANIMAL ORGAN-SYSTEM.	**A.** Sensory Apparatus *Sensorium*	1. Skin-covering (*Derma*)	Outer skin	Epidermis,	I.
			Leather skin	Corium,	II.
		2. Central nerve-system	Brain	Encephalon	I.
			Spinal marrow	Medulla spinalis	
		3. Peripheric nerve-system	Brain nerves	Nervi cerebrales,	I. + II
			Spinal nerves	Nervi spinales,	II.
			Intestinal nerves	Sympatheticus,	II. + III.
		4. Sense-organs (*Organa sensuum*)	Organ of touch (skin)	Org tactus	I. + II
			Organ of taste (tongue)	Org. gustus	
			Organ of smell (nose)	Org. olfactus	
			Organ of sight (eye)	Org. visus	
			Organ of hearing (ear)	Org. auditus	
	B. Motive Apparatus *Locomotorium*	5. Muscle-system (active motive organs)	Skin muscles	Musculi cutane	II.
			Skeleton muscles	M. skeleti	
		6. Skeleton-system (passive motive organs)	Vertebral column	Vertebrarium	
			Skull	Cranium	
			Limb skeleton	Sk. extremitatum	
VEGETATIVE ORGAN-SYSTEM.	**C.** Nutritive Apparatus *Nutritorium*	7. Intestinal system (*Gaster*)	Digestive organ	O. digestiva	III. + IV.
			Respiratory organ	O. respiratoria	
		8. Vascular system (*Organa circulationis*)	Body cavity	Cœloma,	II. + III.
			Lymph vessels	Vasa lymphatica	II. + III.
			Blood vessels	V. sanguifera	
			Heart	Cor,	III.
		9. Renal system (*Organa urinaria*)	Kidneys	Renes	I. (?) + II.
			Urinary ducts	Ureteres	
			Urinary bladder	Urocystis,	III. + IV.
	D. Reproductive Apparatus *Propagatorium*	10. Sexual organs (*Organa sexualia*)	Sexual glands	Gonades	
			(I. Ovary)	(I. Ovaria)	III. + IV. (?)
			(II. Testes)	(II. Testes)	I. + II. (?)
			Sexual ducts	Gonophori	I. (?) + II
			(I. Oviduct)	(I. Oviductus)	
			(II. Seed duct)	(II. Spermaductus)	
			Copulatory organs	Copulativa	I + II.
			(I. Sheath)	(I. Vagina)	
			(II. Penis)	(II. Penis)	

think, securely founded on the Gastrula—that most important of all the germ-forms of the animal kingdom—which we find recurs in similar form in the germ-history of the most different classes of animals. This significant germ-form points unmistakably to a parent-form (the Gastræa) common to all animals, the Protozoa alone excepted; in this long extinct parent-form the entire body of the animal consisted throughout life of the two primary germ-layers, as is yet the case, for a short time, in the Gastrula. In the Gastræa the simple skin-layer did *actually* represent all the animal organs and functions, and the simple intestinal layer, on the other hand, all the vegetative organs and functions; potentially, this is even yet the case in the Gastrula.

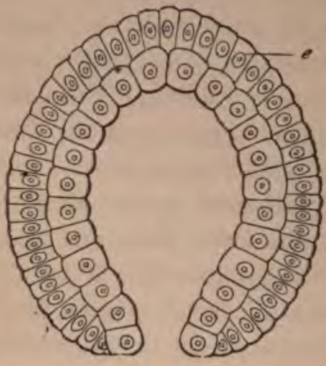
In studying the development of the first important part of the animal sphere, the sensory apparatus, or sensorium, we shall now find how well adapted this Gastræa Theory is to explain, not only in a morphological but in a physiological sense, the most important facts in the history of evolution. This sensory apparatus consists of two very distinct parts, having, apparently, nothing in common: in the first place, the external skin-covering (*Derma*), together with its appendages, the hair, nails, sweat-glands, etc.; and, secondly, the nervous system, situated internally. The latter includes the central nervous system (brain and spinal chord), the peripheric brain-nerves and medullary nerves, and finally, the organs of sense. In the fully developed vertebrate body these two main constituents of the sensorium are entirely separate; the skin lying entirely externally on the body, while the central nervous system is within, and quite separate from the former. The two are connected merely by a portion of the peripheric nerve-system and of the sense-organs. And yet, as we already know from the germ-history of man, the latter is developed from the former. Those organs of our body which discharge the highest and most perfect functions of animal life—those of sensation, volition, thought—in a word, the organs of the psyche, of mental life—arise from the external skin-covering.

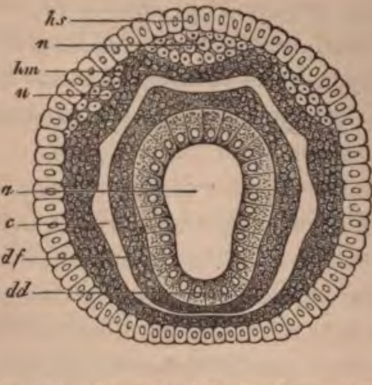
This remarkable fact, considered in itself alone, seems so wonderful, inexplicable, and paradoxical, that the truth of the fact was simply long denied. The most trustworthy embryological observations were met with the erroneous statement that the central nerve-system develops, not from the outer germ-layer, but from a special cell-layer lying underneath this. The ontogenetic fact would not, however, yield; and, now that Phylogeny has thrown light on the subject, the fact seems perfectly natural and necessary. When we reflect on the historic evolution of mind and sense activities, we must necessarily conceive the cells, which accomplish these, as originally situated on the outer surface of the animal-body. Such externally placed elementary organs could alone directly receive and deal with impressions from the outer world. Afterwards, under the influence of natural selection, the complex cell-masses which had become especially "sensitive" gradually withdrew into the shelter of the interior of the body, and there laid the first foundations of a central nervous organ. As differentiation advanced, the distance and distinction between the external skin-covering and the central nervous system detached from this, became continually greater, and finally the two were permanently connected merely by the conductive peripheric nerves.

This view is fully confirmed by the results of Comparative Anatomy. Comparative Anatomy shows that many lower animals possess no nervous system, although, in common with higher animals, they exercise the functions of sensation, volition, and thought. In the Primitive Animals (*Protozoa*), which do not even form germ-layers, of course the nervous system, like the skin-covering, is wanting. Even in the second main division of the animal kingdom—in the Metazoa or Intestinal Animals—there is at first no nervous system. The functions of these are performed by the simple cell-layer of the exoderm, which the lower Intestinal Animals have inherited directly from the Gastræa (Fig. 209, *e*). This is the case in the lowest Plant Animals (*Zoophyta*), the Gastræads, Sponges, and the lowest Hydroid Polyps, which are but little higher than the Gastræads. Just as all the vegetative functions of these are performed by the simple intestinal layer, so all the animal functions are discharged by the equally simple skin-layer. The simple cell stratum of the exoderm is, in these, skin-covering, motive apparatus, and nervous system simultaneously.

Most probably the nervous system was also wanting in a large proportion of those Primitive Worms (*Archelminthes*) which were developed directly from the Gastræads. Even those Primitive Worms in which the two primary germ-layers had already split into the four secondary germ-layers (Plate V. Fig. 10), seem not to have possessed a nervous system distinct from the skin. The skin-sensory layer must, even in these long-extinct Worms, have been at once skin-covering and nerve-system. But already in the Flat Worms (*Platelminthes*), and especially in the Gliding Worms (*Turbellaria*) which of all existing forms approach nearest to the Primitive

Worms, we find an independent nerve-system, distinct and separate from the outer skin-covering. This is the "upper





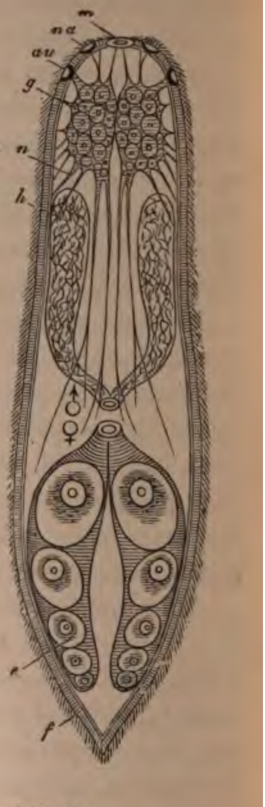


FIG. 209.—Gastrula of Gastrophysema (Gastræad-class).

FIG. 210.—Transverse section through an embryonic Earth-worm: *hs*, skin-sensory layer; *hm*, skin-fibrous layer; *df*, intestinal-fibrous layer; *dd*, intestinal-glandular layer; *a*, intestinal cavity; *c*, body-cavity, or *Cœloma*; *n*, nerve-ganglia; *u*, primitive kidneys.

FIG. 211.—A Gliding Worm (*Rhabdocœlum*). From the brain or upper throat ganglion (*g*) nerves (*n*) radiate towards the skin (*f*), the eyes (*au*), the organ of smell (*na*), and the mouth (*m*): *h*, testes; *e*, ovaries.

throat ganglion," situated above the throat (Fig. 211, *g*; Plate V. Fig. 11, *m*). The complex central nervous system of all higher animals has developed from this simple rudiment. In the higher Worms, *e.g.*, the Earth-worms, according to Kowalevsky, the earliest rudiment of the central nervous system (Fig 210, *n*) is a local thickening of the skin-sensory layer (*hs*), which afterwards becomes entirely detached from the horn-plate. Even the medullary tube of Vertebrates has the same origin. From the germ-history of Man, we already know that this medullary tube, the commencement of the central nervous system, originally develops from the outer skin-covering.

Let us now turn aside from these very interesting features in evolution, and examine the development of the later human skin-covering, with its hairs, sweat-glands, etc. Physiologically, this outer covering (*derma*, or *tegumentum*) plays a double part. The skin, in the first place, forms the general protective covering (*integumentum commune*) which covers the whole surface of the body, and protects all other parts. As such, it, at the same time, effects a certain exchange of matter between the body and the surrounding atmospheric air (perspiration or skin-breathing). In the second place, the skin is the oldest and most primitive sense-organ, the organ of touch, which effects the sensation of the surrounding temperature and of the pressure or resistance of bodies with which it comes in contact.

The human skin, like that of all higher animals, consists essentially of two distinct parts; of the outer-skin, and of the underlying leather-skin. The outer-skin (*epidermis*) consists only of simple cells, and contains no blood-vessels (Fig. 212, *ab*). It develops from the first of the secondary germ-layers from the skin-sensory layer, and, directly, from the horn-plate of the latter. The leather-skin (*corium*), on the contrary, consists principally of connective or fibrous tissue, contains numerous blood-vessels and nerves, and has a different origin. It develops from the outer stratum of the second secondary germ-layer, from the skin-fibrous layer. The leather-skin is much thicker than the outer-skin. In its deeper part, the "*subcutis*," lie many masses of fat-cells (Fig. 212, *h*). Its upper part, the true "*cutis*," or papillary layer, forms, over nearly the whole surface of the body, a number of microscopic cone-shaped warts, or papillæ, which fit into the overlying epidermis (*c*). These touch-warts, or sensory papillæ, contain the most delicate of all the sensory organs of the skin, the "*corpuscula tactus*." Other papillæ

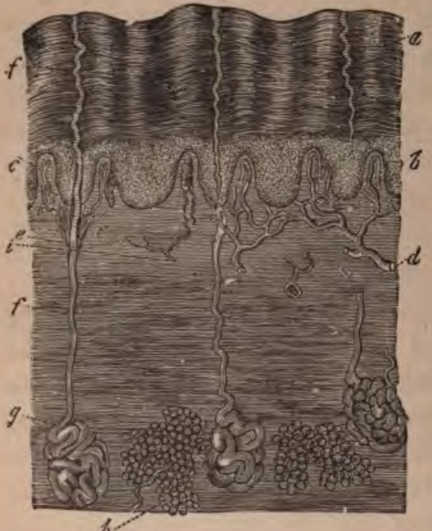
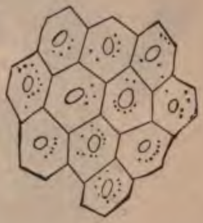


FIG. 212.—Human skin in perpendicular section (after Ecker), much enlarged: *a*, horny stratum of outer-skin (*epidermis*); *b*, mucous stratum of outer-skin; *c*, papillæ of the leather-skin (*corium*); *d*, blood-vessels of the latter; *e*, *f*, excretory ducts of the sweat-glands (*g*); *h*, fat-globules of the leather-skin; *i*, nerve, passing above into a touch-body.

contain merely the terminal loops of the nutritive blood-vessels of the skin (*cd*). All these different parts of the leather-skin originate, by differentiation, from the cells, originally homogeneous, of the leather-plate, the outer lamella of the skin-fibrous layer (Fig. 112, *hpr*, vol. i. p. 352; Plates IV. and V., *l*; Figs. 65–69, *hf*, p. 277).[166]

Analogously, all the constituent parts and appendages of the outer-skin (*epidermis*) originate, by differentiation, from the homogeneous cells of the horn-plate (Fig. 213). At a very early period, the simple cell-layer of this horn-plate splits into two distinct strata. The inner, softer stratum (Fig. 212, *b*) is called the mucous layer; the outer, harder stratum (*a*), the horn-layer of the outer-skin. The surface of this horn-layer is continually worn out and thrown off; new cell-strata, produced by the growth of the underlying mucous layer, take its place. Originally the outer-skin forms an entirely simple cover over the surface of the body. Afterwards, however, sundry appendages develop from this both internally and externally. The internal appendages are the skin-glands; the sweat-glands, the sebaceous glands, etc. The external appendages are hair, nails, etc.

FIG. 213.—Cells of the outer-skin (*epidermis*) of a human embryo of two months. (After Koelliker.)



The glands of the skin-covering are at first merely solid plug-shaped growths of the outer-skin (*epidermis*), which penetrate into the underlying leather-skin (*corium*) (Fig. 214_1). A canal afterwards forms inside these solid plugs ($_2$, $_3$), either owing to the softening and breaking up of the central cells, or as the result of a fluid internally secreted. Some of these skin-glands remain unbranched, as, for instance, the sweat-glands (*e, f, g*). These glands, which secrete the sweat, are of great length, their ends forming a coil; they never branch, however; and the same is to be said of the glands which secrete the fatty wax of the ears.

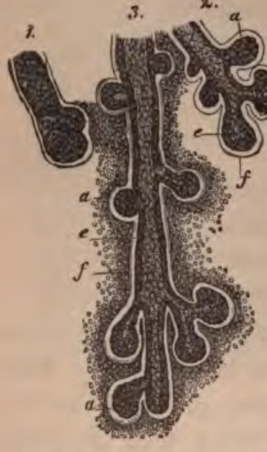
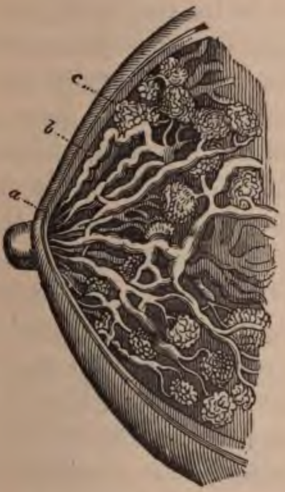


FIG. 214.—Rudiments of tear-glands from a human embryo of four months. (After Koelliker.) 1. Earliest rudiment the shape of a simple, solid plug. 2 and 3. Further developed rudiments, which branch and become hollow: *a*, a solid offshoot; *e*, cell-covering of the hollow offshoot; *f*, rudiment of the fibrous covering, which afterwards forms the leather-skin round the glands.

Most other skin-glands give out shoots and branches, as, for instance, the tear-glands, situated on the upper eyelid, which secrete the tears (Fig. 214), and also the sebaceous glands, which produce the fatty sebaceous matter, and generally opon into the hair-follicles. The sweat and sebaceous glands occur only in Mammals. The tear-glands, on the contrary, are found in all the three classes of Amnion Animals, in Reptiles, Birds, and Mammals. They are not represented in the lower Vertebrates.

Very remarkable skin-glands, found in all Mammals, and in them exclusively, are the milk-glands (*glandulæ mammales*, Figs. 215, 216). They supply milk for the nourishment of the new-born Mammal. Notwithstanding their extraordinary size, these important organs are merely large sebaceous skin-glands (Plate V. Fig. 16, *md*). The milk is produced by liquefaction of the fatty milk-cells within the branched milk-gland pouch (Fig. 215, *c*), just as the sebaceous matter of the skin, and the fatty matter of the hair are produced by the breaking up of fatty sebaceous cells within the sebaceous skin-glands. The excretory passages of the milk-glands enlarge into sac-like milk-ducts (*b*), which again become narrower (*a*), and open, through from sixteen to twenty-four minute apertures, into the nipple of the breast. The first rudiment of this large and complex gland is a very simple conical plug in the



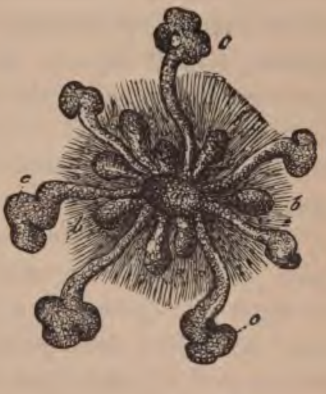


FIG. 215.—The breast of the female in section: *c*, grape-like glandular lobules; *b*, enlarged milk-ducts; *a*, narrow excretory ducts, opening through the breast-nipple. (After H. Meyer.)

FIG. 216.—Milk-glands of a new-born child: *a*, original central gland *b*, smaller, and *c*, larger branches of the latter. (After Langer.)

outer-skin (*epidermis*), which extends into the leather-skin (*corium*), and there branches. In the new-born child it consists merely of from twelve to eighteen radiating lobules (Fig. 216). These gradually branch, the excretory passages become hollow, and a large quantity of fatty matter collects between the lobules. Thus is developed the prominent breast of the female (*mamma*), on the summit of which rises the nipple (*mammilla*), adapted for being sucked.[167] The nipple does not appear until after the milk-gland is already formed; this ontogenetic phenomenon is very interesting, because the more ancient Mammals (the parent-forms of the entire class) had no nipples. In them, the milk simply emerged through a plane, sieve-like perforated spot in the abdominal skin, as is even now the case in the lowest extant Mammals, the Beaked Animals (*Monotremata*; p. 146). On account of this character these animals may be called *Amasta* (without nipple). In many of the lower mammals there are numerous milk-glands, situated at various points of the ventral side. In the human female there is usually only a pair of milk-glands, placed on the point of the breast, as in Apes, Bats, Elephants, and some other Mammals. Occasionally, however, even in the human female two pairs of breast glands (or even more) appear, lying one behind the other; this must be regarded as a reversion to an older parent-form. Sometimes these glands are well developed even in the male, and are capable of being sucked, though as a rule they exist in the male sex only as rudimentary organs without function.

Just as the skin glands originate as local growths of the outer skin in an inward direction, so the appendages of the skin, called hair and nails, originate as local growths of the outer skin in an outward direction. The nails (*ungues*), which are important protective formations over the hind surface of the most sensitive parts of our limbs—the tips of the fingers and toes—are horny products of the epidermis, common to us with the Apes. In their place, the lower Mammals generally possess claws, and the Hoofed Animals (*Ungulata*) hoofs. The parent-form of Mammals undoubtedly had claws, such as appear in a rudimentary state in the Salamander. The hoofs of the Hoofed Animals and the nails of Apes and of Man originated from the claws of more ancient Mammals. In the human embryo the first rudiment of the nails first appears (between the horn-layer and the mucous layer of this outer skin) in the fourth month. Their edges do not, however, project until the end of the sixth month.

The most interesting and important appendages of the outer skin are the hairs, which, on account of their peculiar structure and mode of origin, must be regarded as very characteristic of the whole Mammalian class. Hairs, it is true, appear widely distributed in many lower animals, *e.g.*, in Insects and Worms. But these hairs, like those of plants, are thread-like processes of the outer surface, and differ from Mammalian hairs in their characteristically finer structure and in their mode of development. Hence Oken rightly called Mammals "hairy animals." The hairs of Man, as of all other Mammals, consist simply of epidermic cells peculiarly differentiated and arranged. In their first state, they appear in the embryo as solid plug-shaped processes of the epidermis which penetrate into the underlying leather-skin (*corium*), as do the sebaceous and the sweat glands. As in the latter, the simple plug consists originally of the ordinary epidermic cells. Within this a firmer central cellular mass of conical shape soon forms. This increases considerably in length, detaches itself from the surrounding cellular mass, the "root-sheath," and finally makes its way to the outside, appearing above the outer surface as a hair-stem. The deepest part, buried in the skin, the hair follicle, is the root of the hair, and is surrounded by the root-sheath. In the human embryo the first hairs make their appearance at the end of the fifth or in the beginning of the sixth month.

During the last three or four months before birth the human embryo is usually covered by a thick coating of delicate woolly hairs. This embryonic wool-covering (*lanugo*) is often lost during the last weeks of embryonic life, and, at any rate, soon after birth, when it is replaced by the thinner permanent hair-covering. These later permanent hairs grow out of hair follicles which are developed from the root-sheaths of the deciduous woolly hair. In the human embryo, the embryonic woolly hair usually covers the entire body, with the exception of the palms of the hands and the soles of the feet. These parts remain bare, just as in all Apes and most other Mammals. Not unfrequently the woolly coat of the embryo differs considerably in colour from the later permanent hairy covering. Thus for instance, it sometimes happens in our own Indo-Germanic race that fair-haired parents are shocked to find their children, at their first appearance, covered by a dark brown, or even black, woolly covering It is only after this has been shed, that the permanent fair hair, which the child inherits from its parents, makes its appearance. Occasionally the dark hair is retained for several weeks, or even months, after birth. This remarkable woolly covering can only be explained as an inheritance from our primordial long-haired ancestors, the Apes.

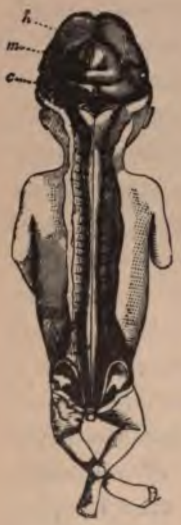
It is equally worthy of note that many of the higher Apes resemble Man in the thin coat of hair which covers certain parts of their body. In most Apes, especially in the higher Catarhines, the face is nearly or even quite bare, or is covered with hairs as thin and as short as those of Man. In these Apes also, just as in Man, the hair on the back of the head is usually distinguished by its length, and the males often have much beard and whisker. (Cf. Fig. 202, p. 175). In both cases this masculine adornment has been acquired in consequence of sexual selection. In some Apes the breast and the inner sides of the joints are very thinly covered with hair—far less abundantly than is the back and the outer sides of the joints. On the other hand, we not unfrequently see the shoulders, the back, and the outer sides of the limbs thickly covered with hair in men of Indo-Germanic or Semitic race. It is a well-known fact that in some families abundant hair on the body is hereditary, as is the relative vigour and character of the hair-growth of the beard and head. These great differences in the total and partial hairiness of the body, which appear very striking not only when we compare different races of man, but even when we compare many families belonging to the same race, are very simply explained by the fact that the entire hairy covering of Man is a rudimentary organ, an unused inheritance, which has been transmitted from the more hirsute Apes. In this matter, Man resembles the Elephant, Rhinoceros, Hippopotamus, Whale, and other Mammals of various orders which have also entirely or partially lost their original coat of hair in consequence of adaptation.[168]

The form of Adaptation which has degraded the growth of hair on most parts of the human body, while preserving it, or even greatly developing it, on certain parts, was, in all probability, sexual selection. As Darwin has very clearly shown in his work on "The Descent of Man," sexual selection has had especially great influence in this respect. In consequence of the male Anthropoid Apes, in selecting a partner, preferring those females which were least hairy, and in consequence of the females preferring those suitors which were distinguished by peculiarly fine beard or head-hair, the general hirsuteness of the body was gradually degraded, while the beard and the hair of the head were advanced to a higher degree of perfection. Climatic conditions, and other circumstances unknown to us, may, however, also have promoted the loss of the hairy coat.

In proof of the assertion that the hairy covering of Man is directly inherited from the Anthropoid Apes, we find, according to Darwin, a curious evidence in the direction, otherwise inexplicable, in which the rudimentary hairs lie on our arms. Both on the upper and on the lower arm the hairs are directed towards the elbow, where they meet at an obtuse angle. Except in Man, this striking arrangement occurs only in the Anthropoid Apes, the Gorilla, Chimpanzee, Orang, and several species of Gibbons. In other Gibbons the hairs of both the lower and the upper arm are directed towards the hand, as in other Mammals. This remarkable peculiarity of Anthropoids and of Man can only be explained on the assumption that our common ape-like ancestors were accustomed, as they are even now, during rain, to bring their hands together over their heads, or over a branch overhanging their heads. The reverse direction of the hairs, when the arms were in this position caused the rain to run off. Thus, even yet, the direction of the hairs on our lower arm testifies to this advantageous habit of our Ape-ancestors.

If the skin and its appendages are minutely examined, Comparative Anatomy and Ontogeny supply many similar important "records of creation," showing that they are directly inherited from the skin-covering of the Ape. We obtained our skin and hair by inheritance, immediately from Anthropoid Apes, these from the lower Apes, which, in turn, inherited the same parts from lower Mammals. This is also true of the other great organ-system which is developed from the skin-sensory layer—of the nervous system and the sensory organs. This very highly developed organ system, which performs the highest vital functions—those of the mind—we have inherited immediately from the Apes, and mediately from Mammals of a lower order.

The human nervous system, like that of all other Mammals, is, in its developed condition, a very complex apparatus, the anatomical arrangement and the physiological activity of which may, in general terms, be compared to a telegraph system. The central marrow (*medulla*), or central nervous system, represents the principal station, the innumerable "ganglion cells" (Fig. 7, vol. i. p. 129) of which are connected with each other and with numerous very delicate conducting lines by their branched processes. The latter are the peripheric "nerve fibres," distributed over the whole surface of the body; these, together with their terminal apparatus, the sense-organs, etc., constitute the "conductive marrow," the peripheric nerve-system. Some, as sensory nerve-fibres, convey the sensations of the skin and of other sense-organs to the central medulla; others, as motor nerve-fibres, transmit the impulses from the central marrow to the muscles.



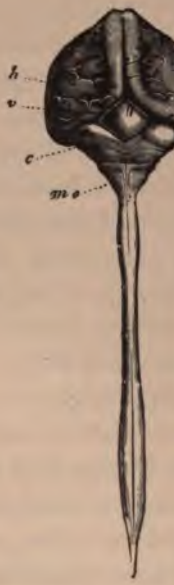


FIG. 217.—Human embryo of three months, in natural size, seen from the dorsal side; the brain and dorsal marrow exposed (after Koelliker): *h*, hemispheres of the cerebrum (fore-brain); *m*, "four-bulbs" (mid-brain); *c*, small brain (hind-brain, or *cerebellum*). Below the latter is the three-cornered "neck-medulla" (after-brain).

FIG. 218.—Central marrow of a human embryo of four months, in natural size, seen from the dorsal side (after Koelliker): *h*, large hemispheres; *v*, "four-bulbs;" *c*, small brain; *mo*, neck-medulla. Below this the dorsal medulla marrow).

The central nervous system, or central marrow (*medulla centralis*), is the actual organ of mental activities, in the stricter sense. Whatever view is taken of the intimate connection between this organ and its functions, it is, at least, certain that those of its special activities which we call sensation, volition, and thought, are in man, as in all the higher animals, inseparably connected with the normal development of this material organ. Hence we must necessarily take a deep interest in the history of the development of this organ. As it alone can give us the most important information as to the nature of our "mind," it commands our most earnest attention. For if the central marrow develops in the human embryo exactly as in the embryos of all other Mammals, then the development of the human mental organ from the same central organ of other Mammals and, more remotely, from that of lower Vertebrates, cannot be questioned. It is, therefore, impossible to dispute the enormous significance of these phenomena of development.

In order to appreciate these rightly, a few words must first be said as to the general form and anatomical construction of the developed central marrow in Man. Like the central nervous system of all other Skulled Animals (*Craniota*), it consists of two distinct parts: firstly, of the brain or the medulla of the head (*encephalon*, or *medulla capitis*), and, secondly, of the spinal marrow (*medulla spinalis*). The former is enclosed in the bony skull, or "brain case," the latter in the bony vertebral canal, which is composed of a consecutive series of vertebræ, shaped like signet rings. (Cf. Plate V. Fig. 16, *m.*) From the brain proceed twelve pairs of head nerves, from the spinal marrow thirty-one pairs of medullary or spinal nerves for the remainder of the body. The spinal marrow, when examined merely anatomically, appears as a cylindrical cord with a spindle-shaped swelling in the region of the neck (at the last of the neck-vertebræ) and another in the lumbar region (at the first lumbar vertebra, Figs. 217, 218). At the swelling at the throat the large nerves of the upper limbs pass off from the spinal marrow, and those of the lower limbs from the swelling in the lumbar region. The upper end of the spinal marrow passes through the neck-marrow (*medulla oblon-*

gata) into the brain. The spinal marrow appears indeed to be a dense mass of nervous substance; but along its axis passes a very narrow canal, which is continued in front into the larger cavities of the brain, and which, like those cavities, is filled with a clear fluid.

The brain forms a considerable mass of nervous substance, of very complex, minute structure, which occupies the greater part of the skull-cavity; it is roughly distinguishable into two main parts—the large and small brain (*cerebrum* and *cerebellum*). The former is situated in front and over the latter, and its surface exhibits the well-known characteristic convolutions and furrows (Figs. 219, 220). On its upper surface it is divided by a deep longitudinal slit into two lateral halves, the so-called "great hemispheres," which are connected by means of a bridge, or "cross-piece" (*corpus callosum*). A deep transverse fissure separates the large brain (*cerebrum*) from the small brain

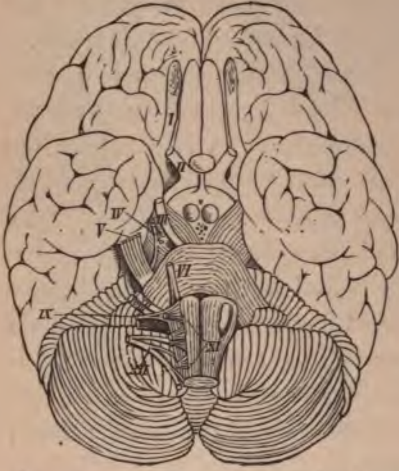


FIG. 219.—Human brain, seen from the lower side. (After H. Meyer.) Above (in front) is the large brain (*cerebrum*), with extensively branched furrows; below (behind) is the small brain (*cerebellum*), with narrow parallel furrows. The Roman numbers indicate the roots of the twelve pairs of brain nerves in order from front to back.

(*cerebellum*). The latter is situated more posteriorly and inferiorly, and shows on its outer surface equally numerous furrows, which are, however, much finer and more regular,

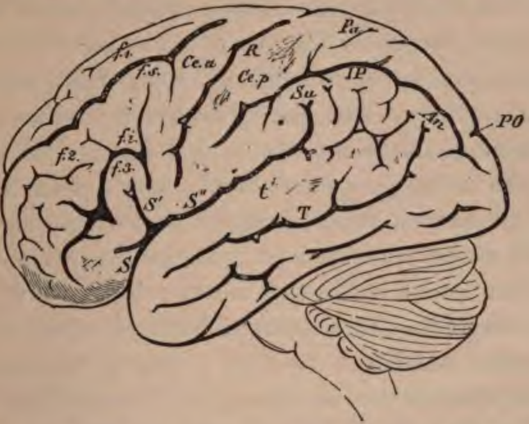


FIG. 220.—Human brain, seen from the left side. (After H. Meyer.) The furrows of the large brain are indicated by large, thick lines, those of the small brain by finer lines. Below the latter the neck-marrow is visible. f^1–f^3, frontal convolutions; *Ce. a Ce. p*, central convolutions; *R*, fissure of Rolandus; *S*, Sylvian fissure; *T*, temporal or parallel fissure; *Pa*, parietal lobe; *An*, the annectant convolutions; *PO*, parieto-occipital fissure; *Su*, supra-marginal convolution; *IP*, intra-parietal fissure; *t*, temporo-sphenoidal convolution.

and between them are curved ridges (Fig. 219, lower part). The small brain is also divided into two lateral halves by a longitudinal furrow; these are the "small hemispheres," which are connected at the top by a worm-like cross-piece, the "brain-worm" (*vermis*), and at the bottom by a bridge (*pons varolii*; Fig. 219, VI.).

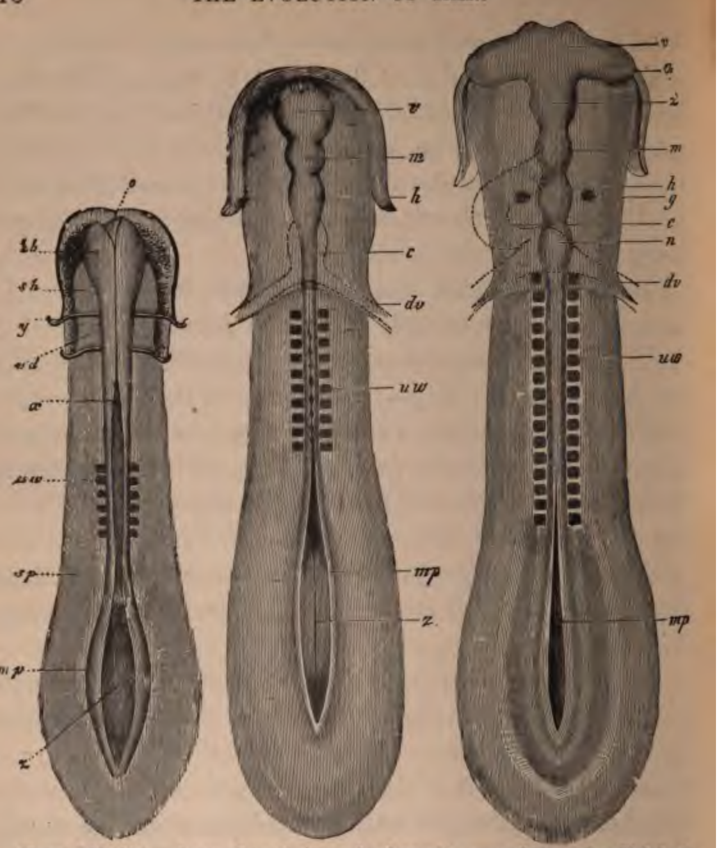
Comparative Anatomy and Ontogeny show, however, that in Man, as in all other Skulled Animals, the brain originally consists not of two but of five distinct parts lying one behind another. These originally appear in the embryo of all

Skulled Animals (*Craniota*), from the Cyclostomi and Fishes up to Man, in exactly the same form, as five bladders placed one behind the other. Alike in their first rudiments, they, however, differ in their further development. In Man and all higher Mammals the first of these five bladders, the fore-brain, develops so excessively that, when mature, it forms, both in size and weight, by far the greater part of the whole brain. To it belong, not only the great hemispheres, but also the bridge (*corpus callosum*), which connects these two, the olfactory lobes, from which proceed the nerves of smell, and most of the processes lying on the roof and floor of the great lateral cavities of the two hemispheres; such, for instance, as the large streaked bodies (*corpora striata*). On the other hand, the "centres of sight," which lie between the streaked bodies, belong to the second main part, which develops from the twixt-brain; and to the same part belong the third brain ventricle (which is single) and the processes known as the "funnel" (*infundibulum*), the gray mass, and the "cone" (*conarium*). Behind these, and between the large brain and the small brain, we find a little mass, composed of two pairs of bosses, and called the "four bulbs," on account of two superficial furrows which cross each other at right angles, thus quartering the whole mass (Figs. 217, *m*, 218, *v*). Though these "four bulbs" are very insignificant in Man and the higher Mammalia, they constitute a distinct part of the brain, the third, or mid-brain, which is, on the contrary, especially well developed in the lower Vertebrates. The next or fourth part of the brain is the hind-brain, or small brain (*cerebellum*), in the strict sense of the term, with its single middle process, the "worm" (*vermis*), and its two lateral parts, the "small hemispheres" (Figs. 217, *c*, 218, *c*). Behind this comes, finally, the fifth and last part, the "neck-marrow" (*medulla oblongata*, Fig. 218, *mo*), which includes the single fourth brain ventricle and the adjoining processes (pyramids, olives, and restiform bodies). The neck medulla passes directly down into the spinal marrow. The narrow central canal of the spinal marrow extends into the wider "fourth ventricle" of the neck medulla, which is rhomboidal in shape, and the floor of which forms the "rhomboid groove." From this proceeds a narrow duct, called the "aqueduct of Sylvius," which leads through the "four-bulbs" into the third ventricle, situated between the two "centres of sight;" and this cavity in turn is connected with the pair of lateral cavities which lie right and left in the large hemispheres. All the cavities of the central marrow are, therefore, directly connected together. Individually all these parts of the brain which we have enumerated have an infinitely complex, minute structure, which we cannot now study, and which hardly bears on our subject. This wonderful brain-structure, as it occurs only in Man and the higher Vertebrates, is of the highest importance, simply because, in all Skulled Animals (*Craniota*), it develops from the same simple rudiments, from the five brain-bladders already enumerated. (Cf. Plates VI. and VII.)

Before we direct our attention to the individual development of the complex brain from this series of simple bladders, we will, in order to understand the matter more clearly, glance for a moment at those lower animals which have no such brain. Even in the skull-less Vertebrates, in the Amphioxus, there is no real brain. In this case the whole central marrow is merely a simple cylindrical cord traversing the body longitudinally, and terminating in front almost as simply as at the other end: it is a simple medullary tube (Plate XI. Fig. 15, m). We found, however, that the rudiment of the same simple medullary tube occurs in the ascidian larva (Plate X. Fig. 5, m) and in the same characteristic position, above the notochord. Moreover, when closely examined a small bladder-like swelling may be seen at the fore end of the medullary tube in these two closely allied animals; this is the first indication of a separation of the medullary tube into brain (m_1) and spinal marrow (m_2). When, however, we consider the undeniable relationship of the Ascidia to the rest of the Worms, it is evident that the simple central marrow of the former exactly answers to the simple nerve-ganglion which, in the lower Worms lies above the throat (*pharynx*), and which has, therefore, long been called the "upper throat ganglion" (*ganglion pharyngeum superius*). In the Gliding Worms (*Turbellaria*) the whole nerve system consists merely of this simple ganglion, which is situated on the dorsal side of the body, and from which nerve-threads radiate to the different parts of the body (Fig. 211, *gn*) This upper throat ganglion of the lower Worms is evidently the rudiment from which the more complex central marrow of the higher animals has developed. An elongation of the upper throat ganglion along the dorsal side gave rise to the medullary tube, which is characteristic of Vertebrates and the young forms of Ascidia alone. On the other hand, in all other animals, the central nerve system has developed in a very different manner from the upper throat ganglion; in Articulated Animals (*Arthropoda*) especially, the latter has developed into a throat (pharyngeal) ring, with a ventral marrow; this is the case, also, in the articulated Ringed Worms (*Annelida*) and the Star-animals (*Echinoderma*), which originated from Arthropods. The Soft-bodied Animals (*Mollusca*) also have a throat ring, which is quite unrepresented in Vertebrates. Only in Vertebrates the central marrow developed along the dorsal side, while in all other animals which have been named it developed along the ventral side of the body.[169]

Descending below the Worms we find very many animals which are entirely without a nerve-system, and in which the functions of that system are performed simply by the outer skin-covering—by the cells of the skin-layer, or exoderm. This is the case in many low Plant Animals (*Zoophyta*), for instance, in all Sponges, and in the common fresh-water Polyp, the Hydra. It was also undoubtedly the case in all extinct Gastræads. In all Primitive Animals (*Protozoa*) the nerve-system is, of course, unrepresented, for these have not as yet attained to the development of germ-layers.

In considering the individual development of the nerve-system in the human embryo, we must first of all start from the important fact already mentioned, that the first rudiment of the system is the simple medullary tube, which detaches itself from the outer germ-layer along the middle line of the lyre-shaped primitive germ. We found (Figs. 85–87, vol. i. p. 298) that the rectilineal primitive groove, or dorsal furrow, first arises in the centre of the lyre-shaped germ-disc. On each side of this rise the two parallel dorsal or medullary swellings. The free margins of these bend towards each other, coalesce, and form the closed medullary tube (Figs. 88–93, vol. i. pp. 300–309). At first this tube lies directly under the horn-plate; it is, however, afterwards situate

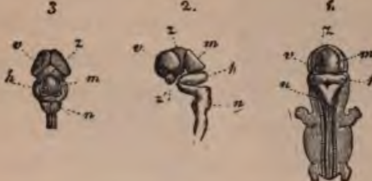


FIGS. 221–223.—Lyre-shaped (or sole-shaped) germ-shield of a Chick, in three consecutive stages of evolution, seen from the dorsal surface: about twenty times enlarged. Fig. 221, with six pairs of primitive vertebræ. The brain a simple bladder (*hb*). The medullary furrow is wide open from the point *x*, very wide at *z*. *mp*, Marrow (or medullary) plates; *sp*, side-plates; *y*, boundary between the throat cavity (*sh*) and the head-intestine (*vd*). Fig. 222, with ten pairs of primitive vertebræ. The brain consists of three bladders: *v*, fore-brain; *m*, mid-brain; *h*, hind-brain. *c*, Heart; *dv*, yelk-veins. The medullary furrow is wide open behind (*z*). *mp*, Marrow-plates. Fig. 223, with sixteen pairs of primitive vertebræ. The brain consists of five bladders: *v*, fore-brain; *z*, twixt-brain; *m*, mid-brain; *h*, hind-brain; *n*, after-brain. *a*, Eye-vesicles; *g*, ear-vesicles; *c*, heart; *dv*, yelk-veins; *mp*, marrow-plate. *uw*, primitive vertebræ.

quite internally, the upper edges of the primitive vertebral plates, which penetrate, from right and left, in between the horn-plate and the medullary tube, uniting above the latter, and thus completely embedding it in a closed canal. As Gegenbaur most aptly remarks, "This gradual embedding in the interior of the body must be regarded as an incident acquired in connection with progressive differentiation, and with the consequent higher capacity, by which the most important organ of the system is secured in its interior."

To every thoughtful and unprejudiced man it must appear an extremely important and pregnant fact, that our mental organ, like that of all other Skulled Animals (*Craniota*), commences in the same way and in exactly the same simple form in which this organ remains for life in the lowest Vertebrate, the Amphioxus (vol. i. p. 420, Fig. 151; Plate XI. Fig. 15, *m*). In the Cyclostomi, that is, in the stage above the Acrania, the anterior extremity of the cylindrical medullary tube begins to extend, at an early period, in the form of a pear-shaped bladder, which is the first distinct rudiment of a brain (Plate XI. Fig. 16, m_1). For the central medulla of Vertebrates thus first distinctly differentiates into its two main sections, the brain (m_1) and the spinal marrow (m_2). The first faint indication of this important differentiation is discoverable in the Amphioxus, perhaps even in the Ascidian larva (Plate X. Fig. 5).

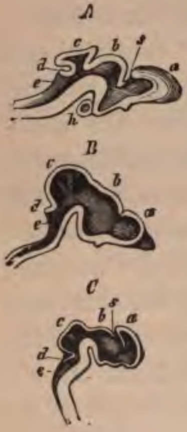
The simple bladder-like form of the brain, which is retained for a considerable time in the Cyclostomi, also appears at first in all higher Vertebrates (Fig. 221, *hb*). In the latter, however, it soon disappears, in consequence of the separation of the simple brain-bladder, by transverse contractions of its circumference, into several consecutive parts. Two of these contractions first appear, and consequently the brain forms three consecutive bladders (Fig. 222, *v*, *m*, *h*). The first and third of these three primitive bladders then again separate by transverse contractions, each into two parts, and thus five consecutive bladder-like divisions are formed (Fig. 223: cf. also Plate V. Figs. 13–16; Plates VI. and VII., second cross-line). These five fundamental brain-bladders, which re-occur in the same form in the embryos of all the Skulled Animals (*Craniota*), were first clearly recognized by Baer, who understood their true importance and distinguished them, according to their relative positions, by very appropriate names, which are still in general use: I., fore-brain (*v*); II., twixt-brain (*z*); III., mid-brain (*m*); IV., hind-brain (*h*); and V., after-brain (*n*).

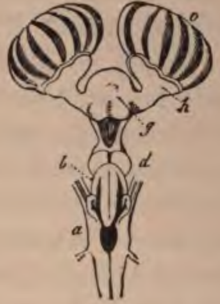


FIGS. 224–226.—Central marrow of human embryo in the seventh week, two cm. long. (After Koelliker.) Fig. 226, view of the whole embryo from the dorsal side; the brain and dorsal marrow laid bare. Fig. 225, the brain and upper part of the dorsal marrow from the left side. Fig. 224, the brain from above: *v*, fore-brain; *z*, twixt-brain; *m* mid-brain; *h*, hind-brain; *n*, after-brain.

In all Skulled Animals, from the Cyclostomi to Man, the same parts, although in very various forms, develop from these five original brain-bladders. The first bladder, the fore-brain (*protopsyche, v*), forms by far the largest part of the so-called "great brain" (*cerebrum*); it forms the two great hemispheres, the olfactory lobes, the streaked bodies (*corpora striata*), and the cross-piece (*corpus callosum*), together with the "arch" (*fornix*). From the second bladder, the twixt-brain (*deutopsyche, z,*) proceed primarily the "centres of sight" and the other parts which surround the so-called "third brain-ventricle," also the "funnel" (*infundibulum*), the "cone" (*conarium*), etc. The third bladder, the mid-brain (*mesopsyche, m*), furnishes the small group of the "four bulbs," together with the "aqueduct of Sylvius." From the fourth bladder, the hind-brain (*metapsyche, h*), the greater part of the so-called "little brain" (*cerebellum*) develops; the central "worm" (*vermis*), and the two lateral "small hemispheres." The fifth bladder, finally, the after-brain (*epipsyche, n*), forms the neck-marrow, or the "elongated marrow" (*medulla oblongata*), together with the rhomboid groove, the pyramids, olives, etc.

The very highest importance must certainly be ascribed to the fact, seen in Comparative Anatomy and Ontogeny, that the brain is originally formed in exactly the same way in the embryos of all Skulled Animals (*Craniota*), from the lowest Cyclostomi and Fishes, to Apes and Man. In all, the first rudiment of the brain is a simple bladder-like expansion at the anterior extremity of the medullary tube. In all, the five bladders are formed from this simple bladder-like expansion, and in all, these five primitive brain-bladders develop into the permanent brain, with its many complex anatomical arrangements, which afterwards appear in such extremely diverse forms in the various vertebrate classes. On comparing the mature brain of a Fish, an Amphibian, a Reptile, a Bird, and a Mammal, it is hardly conceivable that the several parts of these forms, so extremely different, both internally and externally, may be traced back to one common condition. And yet, all these various brains of Craniota have originated from exactly the same rudimentary form. We need only compare the embryos of these various classes of animals at corresponding stages of development, in order to assure ourselves of this fundamental fact. (Cf. Plates VI. and VII., second cross-line.)





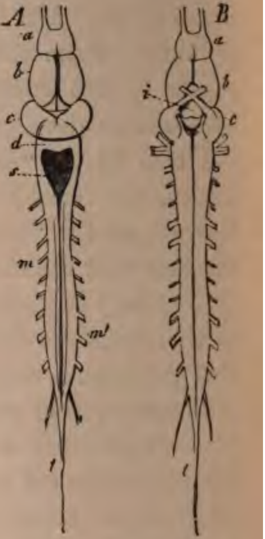


FIG. 227.—Brains of three embryonic Skulled Animals in vertical longitudinal sections: *A*, of a Shark (*Heptanchus*); *B*, of a Snake (*Coluber*); *C*, of a Goat (*Capra*); *a*, fore-brain; *b*, twixt-brain; *c*, mid-brain; *d*, hind-brain; *e*, after-brain; *s*, primitive fissure of the brain. (After Gegenbaur.)

FIG. 228.—Brain of a Shark (*Scyllium*) from the dorsal side: *g*, fore-brain; *h*, olfactory bulbs of the fore-brain, which send the large olfactory nerves to the large nose capsules (*o*); *d*, twixt-brain; *b*, mid-brain (behind it, the insignificant rudiment of the hind-brain); *a*, after-brain. (After Busch.)

FIG. 229.—Brain and dorsal marrow of a Frog: *A*, from the dorsal side; *B*, from the ventral side; *a*, olfactory bulbs, in front of the fore-brain (*b*); *i*, funnel at the base of the twixt-brain; *c*, mid-brain; *d*, hind-brain; *s*, rhomboid groove in the after-brain; *m*, dorsal marrow (very short in the frog); *m'*, root-processes of the spinal nerves; *t*, fibre at the end of the dorsal marrow. (After Gegenbaur.)

A thorough comparison of the corresponding stages of development in the brain in the various Skulled Animals (*Craniota*) is very instructive. If it is applied to the whole series of skulled classes, the following extremely interesting facts soon become evident: in the Cyclostomi (*Myxinoides* and *Petromyzontes*), which, as we have seen, are the lowest and earliest Skulled Animals, the whole brain remains for life at a very low and primitive stage of development, through which the embryos of the other Skulled Animals pass very rapidly; the five original sections of the brain are visible throughout life in an almost unmodified form. But even in Fishes, an essential and important transformation of the five bladders takes place; it is evidently from the brain of the Primitive Fishes (Selachii; Fig. 228), that, on the one side, the brain of the other Fishes, and on the other, the brain of the Amphibians and also of the higher Vertebrates, must be traced. In Fishes and Amphibians (Fig. 229), the central part, the mid-brain, and also the fifth section, the after-brain, are especially developed, while the first, second, and fourth sections remain far behind. In the higher Vertebrates, the exact reverse is the case, for in these the first and fourth sections, the fore and hind brains, develop pre-eminently; on the other hand, the mid-brain remains very small, and the after-brain is also much smaller. The greater part of the "four-bulbs" is covered by the large brain (*cerebrum*) and the after-brain by the small brain (*cerebellum*). Even among the higher Vertebrates themselves, numerous gradations occur in the structure of the brain. From the Amphibians upward, the brain, and with it the mental life, develops in two different directions, of which the one is carried out in Reptiles and Birds, the other in Mammals. The latter are especially distinguished by the very characteristic development of the first section, the fore-brain. In

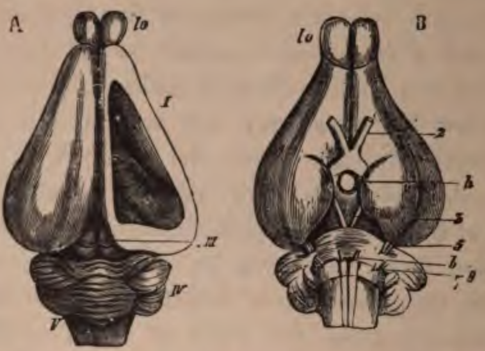


FIG. 230.—Brain of Rabbit: *A*, from the dorsal side; *B*, from the ventral side; *lo*, olfactory lobules; I., fore-brain; *h*, hypophysis at the base of the twixt-brain; III., mid-brain; IV., hind-brain; V., after-brain; 2, optic nerve; 3, motor nerve of the eye; 5–8, fifth to eighth nerves of the brain. In *A*, the upper surface of the right large hemisphere (I.) is removed, so that the streaked bodies (*corpora striata*) can be seen in its side chamber (*ventriculus lateralis*). (After Gegenbaur.)

Mammals alone (Fig. 230) does this "great brain" develop to such an extent, that it eventually covers all the other parts of the brain from above.

There are also remarkable differences in the relative positions of the brain-bladders. In the lower Skulled Animals the five brain-bladders are at first situated one behind the other in the same plane. If the brain is regarded from the side, a straight line may be drawn through all the five bladders. But in the three higher vertebrate classes, in the Amnion Animals (*Amniota*), a noticeable curving of the rudimentary brain takes place, simultaneously with the head and neck curving of the whole body, owing to the fact that the whole upper dorsal surface of the brain grows much faster than the lower ventral surface. The result is that the brain is so curved that its parts are afterwards situated thus: the fore-brain lies quite in front and below, the twixt-brain somewhat higher and over it, while the mid-brain lies highest of all and projects furthest forward; the hind-brain is situated lower, the after-brain yet further back and below. This disposition occurs only in the three classes of the Amniota, in Reptiles, Birds, and Mammals. (Cf. Plates I., VI., and VII.)

Though, in general features of growth, the brains of Mammals correspond with those of Birds and Reptiles, yet striking differences very soon appear between the two. In Birds and Reptiles (Plate VI. Figs. *H* and *C*), the mid-brain (*m*) and the central part of the hind-brain develop considerably. In Mammals, on the other hand, these parts remain small, and instead, the fore-brain begins to grow so rapidly that it covers the other bladders from in front and above. As it constantly grows further back, it eventually covers the whole of the rest of the brain above, and also encloses the central part from the sides. This process is of the greatest importance, because this fore-brain is the organ of the higher mental activities,—because in it are accomplished those functions of the nerve-cells, the sum of which is generally designated as the mind, or the "spirit" in the narrower sense. The highest activities of the animal body, the wonderful manifestations of consciousness, the complex phenomena of the activities of thought, have their seat in the fore-brain. It is possible to remove the great hemispheres of a Mammal, piece by piece, without killing the animal, thus proving that the higher mental activities, consciousness and thought, conscious volition and sensation, may be destroyed one by one, and finally entirely annihilated. If the animal thus treated is artificially fed, it may be kept alive for a long time; for the nourishment of the entire body, digestion, respiration, the circulation of the blood, secretion, in short, the vegetative functions, are in no way destroyed by this destruction of the most important mental organs. Conscious sensation and voluntary motion, the capacity for thought and the combination of the various higher mental activities, have alone been lost.

This fore-brain, the source of all these most wonderful nervous activities, reaches that high degree of perfection only in the higher Placental Animals (*Placentalia*); a fact which explains very clearly why the higher Mammals so far excel the lower in intellectual capacity. While the "mind" of the lower Placental Animals does not exceed that of Birds and Reptiles, we find among the higher Placentalia an uninterrupted gradation up to Apes and Man. Accordingly, their anterior brains show surprising differences in the degree of perfection. In the lower Mammals, the surface of the great hemispheres (the most important part) is entirely smooth and even. The fore-brain, too, remains so small that it does not even cover the mid-brain above (Fig. 230). One stage higher, and this latter is indeed entirely covered by the excessive growth of the fore-brain; but the hind-brain remains free and uncovered. At last, in Apes and in Man, the fore-brain covers the hind-brain also. A similar gradual advance may also be traced in the development of the peculiar furrows and protuberances which are so characteristically prominent on the surface of the large brain (*cerebrum*) of higher Mammals (Figs. 219, 220). If the brains of the various mammalian groups are compared with reference to these convolutions and furrows, it appears that their gradual development is entirely proportionate with the development of the higher intellectual activities. Much attention has recently been devoted to this particular branch of the Anatomy of the brain, and very striking individual differences have been found even within the human race. In all human individuals distinguished by peculiar ability and great intellect, these swellings and furrows on the surface of the great hemispheres exhibit a much greater development than in common average men; while in the latter, again, they are more developed than in Cretins and others of unusually feeble intellect. There are also similar gradations in the internal structure of the fore-brain in Mammals. The great cross-piece (*corpus callosum*), especially, the bridge between the two great hemispheres, is developed only in Placental Animals. Other arrangements, for example, in the structure of the lateral cavities, which seem primarily to be peculiar to Men as such, re-appear only in the higher species of Apes. It was long believed that Man had some entirely peculiar organs in the great brain (*cerebrum*), which are wanting in all other animals. But close comparison has shown that this is not the case, but that rather the characteristic qualities of the human brain exist in a rudimentary state even in the lower Apes, and are developed to a greater or less degree in the higher Apes. Huxley, in his important and much-quoted book, "Evidence as to Man's Place in Nature" (1863), has shown, most convincingly, that within the Ape-series the differences in the formation of the brain are greater between the higher and lower Apes than between the higher Apes and Man. This statement is, indeed, equally true of all the other parts of the body. But the fact that it is true of the central marrow is especially important. This does not become fully evident unless these morphological facts are considered in connection with the corresponding physiological phenomena; until we consider that every mental activity requires for its complete and normal exercise the complete and normal condition of the corresponding brain-structure. The extremely complex and perfect active phenomena within the nerve-cells, summed up in the word "mental life," can no more exist without their organs in the vertebrates, including man, than can the circulation of the blood without a heart or blood. As, however, the central marrow of Man has developed from the same medullary tube as in all other Vertebrates, so also must the mental life of Man have had the same origin.

All this is of course true of the conductive marrow, or the so-called "peripheric nervous system." This consists of the *sensitive* nervous fibres which convey the impressions of sensation from the skin and the organs of the senses in a centripetal direction to the central marrow; as well as of the *motor* nervous fibres, which, reversely, convey the movements of volition from the central marrow, in a centrifugal direction to the muscles. By far the greater part of these peripheric conductive nerves originates from the skin-fibrous layer, by peculiar local differentiation of the rows of cells into the respective organs.

The membranous coverings and blood-vessels of the central marrow are identical in origin with the greater part of the conductive marrow; these membranous coverings are the inner membrane (*pia mater*), the central membrane (*meninx arachnoides*), and the outer membrane (*dura mater*). All these parts are developed from the skin-fibrous layer.

TABLE XXVII.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE HUMAN SKIN-COVERINGS.

I. *First Period: Skin of Gastræads.*

The entire skin-covering (including the nervous system, not yet differentiated from it) consists of one simple layer of ciliated cells (exoderm, or primary skin-layer); as it is at the present day in the gastrula of the Amphioxus.

II. *Second Period: Skin of Primitive Worms.*

The simple exoderm of the Gastræad has thickened and split into two distinct layers, or secondary germ-layers: the skin-sensory layer (rudiment of the horn-plate and nerve-system) and the skin-fibrous layer (rudiment of the leather skin (*corium*), the muscle-plate and the skeleton-plate. The skin is potentially both covering and mind.

III. *Third Period: Skin of Chordonia.*

The skin-sensory layer has differentiated into the horn-plate (*epidermis*), and the central marrow (upper throat ganglia) separated from it; the latter elongates into a medullary tube. The skin-fibrous layer has differentiated into the leather plate (*corium*) and, below this, the skin-muscular pouch (as in all Worms).

IV. *Fourth Period: Skin of Acrania.*

The horn-plate yet forms a simple epidermis. The leather-plate is fully differentiated from the muscle and skeleton plates.

V. *Fifth Period: Skin of Cyclostoma.*

The outer-skin remains a simple, soft mucous layer of cells, but forms one-celled glands (cup-cells). The leather-skin (*corium*) differentiates into *cutis* and *sub-cutis.*

VI. *Sixth Period: Skin of Primitive Fishes.*

The outer skin is still simple. The leather skin forms placoid scales or small bony tablets, as in the Selachii.

VII. *Seventh Period: Skin of Amphibia.*

The outer skin differentiates into an outer horn-layer, and an inner mucous layer. The ends of the toes are covered with horny sheaths (first rudiments of claws or nails).

VIII. *Eighth Period: Skin of Mammals.*

The outer skin forms the appendages characteristic of Mammals only; hair, and sebaceous, sweat, and milk glands.

TABLE XXVIII.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE HUMAN NERVOUS SYSTEM.

I. *First Period: Medulla of Gastræads.*

The nerve system is not yet distinct from the skin, and, together with the latter, is represented by the simple cell-stratum of the exoderm, or primary skin-layer; as it is at the present day in the gastrula of the Amphioxus.

II. *Second Period: Medulla of Primitive Worms.*

The central nerve system is yet, at first, a part of the skin-sensory layer, and afterwards consists of a throat medulla, a simple nerve-ganglion lying above the throat; as it is now in the lower Worms: the upper throat ganglion.

III. *Third Period : Medulla of Chordonia.*

The central nerve system consists of a simple medullary tube, an elongation of the upper throat ganglion, which is separated from the intestine by a notochord (*chorda dorsalis*).

IV. *Fourth Period : Medulla of Acrania.*

The simple medullary tube differentiates into two parts: a head, and a dorsal part. The head medulla resembles a small, pear-shaped, simple swelling (the primitive brain, or first rudiment of the brain) on the anterior extremity of the long cylindrical spinal marrow.

V. *Fifth Period: Medulla of Cyclostoma.*

The simple, bladder-like rudiment of the brain divides into five consecutive brain-bladders of simple structure.

VI. *Sixth Period : Medulla of Primitive Fishes.*

The five brain-bladders differentiate into a form similar to that now permanently retained by the Selachii.

VII. *Seventh Period : Medulla of Amphibia.*

The differentiation of the five brain-bladders progresses to that structure which is now characteristic of the brain in Amphibia.

VIII. *Eighth Period : Medulla of Mammals.*

The brain attains the characteristic peculiarities distinctive of Mammals. The following may be distinguished as subordinate stages of development; 1, the brain of Monotremes; 2, the brain of Marsupials; 3, the brain of Semi-apes; 4, the brain of Apes; 5, the brain of Man-like Apes; 6, the brain of Ape-men; and 7, the brain of Man.

TABLE XXIX.

Systematic Survey of the Evolution of the Skin-covering and Nerve System.

XXIX. *A.* Survey of the Evolution of the Skin-covering.

Skin (*Derma*, or *Integumentum*)	Outer-skin (*Epidermis*) Product of the Skin-sensory-layer	Horn-layer of the outer skin (*Stratum corneum*) Mucous layer of the outer skin (*Stratum mucosum*)	Hair Nails Sweat glands Tear glands Sebaceous glands Milk glands
	Leather-skin (*Corium*) Product of the Skin-fibrous-layer	Fibrous layer of the leather skin (*Cutis*) Fatty layer of the leather skin (*Subcutis*)	Connective tissue Fatty tissue Muscular tissue Blood-vessels Papillæ of taste and nerves of the leather skin

XXIX. *B.* Survey of the Evolution of the Central Marrow.

Central Marrow, or **Central Nerve System** (*Psyche*, or *Medulla Centralis*). Product of the **Skin-sensory layer**	I. Fore-brain (*Protopsyche*)	Great hemispheres	*Hemisphæræ cerebri*
		Olfactory lobules	*Lobi olfactorii*
		Lateral chambers	*Ventriculi laterales*
		Streaked bodies	*Corpora striata*
		Arch	*Fornix*
		Cross piece	*Corpus callosum*
	II. Twixt-brain (*Deutopsyche*)	Centre of sight	*Thalami optici*
		Third chamber of the brain	*Ventriculus tertius*
		Pineal body	*Conarium*
		Funnel	*Infundibulum*
	III. Mid-brain (*Mesopsyche*)	Four bulbs	*Corpus bigeminum*
		Aqueduct of Sylvius	*Aquæductus Sylvii*
		Brain stalks	*Pedunculi cerebri*
	IV. Hind-brain (*Metapsyche*)	Small hemispheres	*Hemisphæræ cerebelli*
		Brain worm	*Vermis cerebelli*
		Brain bridge	*Pons Varolii*
	V. After-brain (*Epipsyche*)	Pyramids	*Corpora pyramidalia*
		Olives	*Corpora olivaria*
		Restiform bodies	*Corpora restiformia*
		Fourth chamber of the brain	*Ventriculus quartus*
	VI. Dorsal Marrow	*Notopsyche*	*Medulla spinalis*
Medullary coverings (*Meninges*)	Enveloping membranes, with the nutritive blood-vessels of the brain and spinal cord	1. Soft medullary skin	*Pia mater*
		2. Central medullary skin	*Arachnoidea*
		3. Hard medullary skin	*Dura mater*
		(Products of the skin-fibrous layer)	

CHAPTER XXI.

DEVELOPMENT OF THE SENSE-ORGANS.

Origin of the most highly Purposive Sense-organs by no Preconceived Purpose, but simply by Natural Selection.—The Six Sense-organs and the Seven Sense-functions.—All the Sense-organs originally Developed from the Outer Skin-covering (from the Skin-sensory Layer).—Organs of the Pressure Sense, the Heat Sense, the Sexual Sense, and the Taste Sense.—Structure of the Organ of Scent.—The Blind Nose-pits of Fishes.—The Nasal Furrows change into Nasal Canals.—Separation of the Cavities of the Nose and Mouth by the Palate Roof.—Structure of the Eye.—The Primary Eye Vesicles (Stalked Protuberances from the Twixt-brain).—Inversion of this Eye Vesicle by the Crystalline Lens, separated from the Horn-plate.—Inversion of the Vitreous Body.—The Vascular Capsule and the Fibrous Capsule of the Eyeball.—Eyelids.—Structure of the Ear.—The Apparatus for Perception of Sound: Labyrinth and Auditory Nerve.—Origin of the Labyrinth from the Primitive Ear Vesicles (by Separation from the Horn-plate).—Conducting Apparatus of Sound: Drum Cavity, Ear Bonelets, and Drum Membrane.—Origin of these from the First Gill-opening and the Parts immediately round it (the First and Second Gill-arch).—Rudimentary Outer Ear.—Rudimentary Muscles of the Ear-shell.

"Systematic Physiology is based especially upon the history of development, and unless this is more complete, can never make rapid progress; for the history of development furnishes the philosopher with the materials necessary for the secure construction of a system of organic life. Hence anatomical and physiological researches should be prosecuted more from the point of view of development than is now the case; that is, we should study each organ, each tissue, and even each function simply with the view of determining *whence they have arisen.*"—EMIL HUSCHKE (1832).

THE sense-organs are undeniably among the most important and most interesting parts of the human body; through their activity alone we recognize the objects in the world around us. "Nihil est in intellectu, quod non prius fuerit in sensu." They are the true springs of our mental life. In no other part of the animal body can we point to such extremely delicate and complex anatomical contrivances, co-operating for a definite physiological aim; and in no other part of the body do these wonderful and very apt contrivances seem, at first, to indicate a premeditated creative design so conclusively. Hence it is that, in accordance with the received teleological view, it has been customary to admire the so-called "wisdom of the Creator" and the "purposive contrivances of His Creation" especially in this matter. But on more mature consideration it will be observed that the Creator, according to this conception, does after all but play the part of an ingenious mechanic or of a skilful watchmaker; just, indeed, as all these cherished teleological conceptions of the Creator and His Creation are based on childish anthropomorphism.

We admit that at first sight this teleological explanation seems to afford the simplest and fittest interpretation of these very apt contrivances. If the structure and functions of the very highly developed sense-organs are alone regarded, it seems as though their origin is hardly explicable except on the assumption of a supernatural creative act. But it is exactly on this point that the history of evolution proves most clearly that this received conception is radically false. The history of evolution convinces us that the highly purposive and admirably constituted sense organs, like all other organs, have developed without premeditated aim; that they originated by the same mechanical process of Natural Selection, by the same constant interaction of Adaptation and Heredity, by which all the other purposive contrivances of the animal organization have been slowly and gradually evolved during the "Struggle for Existence."

Like most other Vertebrates, Man possesses six distinct organs of sense, which accomplish seven distinct sensations. The external skin-covering accomplishes the sensation of pressure (resistance) and of temperature (warmth and cold). This is the earliest, the lowest, and the least differentiated organ of sense; it is distributed over the entire surface of the body. The other sensorial activities are localized. The sexual sense is limited to the skin-covering of the external sexual organs, just as the sense of taste is limited to the mucous membrane of the mouth-cavity (tongue and palate), and the sense of smell to the mucous membrane of the nose-cavity. Special mechanical contrivances of great complexity exist for the two highest and most differentiated organs of sense, the eye for the sense of sight, and the ear for that of hearing.

Comparative Anatomy and Physiology show that in the low animals specialized sense-organs are entirely wanting, and that all sensations are transmitted through the outer surface of the skin-covering. The undifferentiated skin-layer, or exoderm, of the Gastræa is the simple cell-layer from which the differentiated sense-organs of all Intestinal Animals (*Metazoa*), and, therefore, of all Vertebrates, originally developed. Starting from the consideration that necessarily only the most superficial parts of the body, those immediately exposed to the outer world, could have accomplished sensations, we should be justified in conjecturing *à priori* that the organs of sense also owe their origin to the same part. This is, indeed, the fact. The most important part of all sense-organs develops from the outermost germ-layer, from the skin-sensory layer; in part, directly from the horn-plate, and, in part, from the brain, the foremost section of the medullary tube, after this has separated from the horn-plate. On comparing the individual development of the various organs of sense, we see that at first they make their appearance in the simplest conceivable form: only very gradually does that wonderful perfect structure develop by which the higher sense-organs eventually become the most remarkable and the most complex mechanisms of the entire organization. All organs of sense are, however, originally merely portions of the external skin-covering, in which sensorial nerves are distributed. Even these nerves were originally homogeneous and undifferentiated in character. Gradually, by division of labour, the various functions or "specific energies" of the different sensorial nerves developed. Simultaneously the simple terminal expansions of these sense nerves in the skin-covering developed into extremely complex organs.

The important bearings of these historic facts upon the just appreciation of mental life will readily be perceived. The whole philosophy of the future will assume another form as soon as Psychology has gained an accurate knowledge of these genetic facts, and has made them the basis of its speculations.

If the psychological teachings, published by the best-known speculative philosophers, and still generally received, are impartially studied, the simplicity with which the authors bring forward their airy metaphysical speculations, regardless of all the significant ontogenetic facts by which their doctrines are clearly refuted, cannot fail to cause great surprise. And yet the history of evolution, in conjunction with the rapidly advancing Comparative Anatomy and Physiology of the sense-organs, affords the only safe foundation for the natural theory of the mind.

With reference to the terminal expansions of the sensory nerves, the human organs of sense may be distributed into three groups, corresponding to three different stages of development. The first group includes those sense-organs, the nerves of which distribute themselves simply in the free surface of the skin-covering (organs of the sense of pressure, of heat, and of the sexual sense). In the second group, the nerves distribute themselves in the mucous membrane of cavities, which are originally grooves or inversions of the skin-covering (organs of taste and of smell). Finally, the third group is constituted by those very highly developed sense-organs, the nerves of which distribute themselves over an internal vesicle detached from the skin-covering (organs of sight and hearing). This remarkable genetic relation is represented in the following table:—

Three Groups.	*Sense-organs.*	*Sense-nerves.*	*Sense-functions.*
A. Sense-organs in which the terminal expansions of the nerves are distributed in the outer skin-covering.	I. Skin-covering (outer skin, or *epidermis*, and leather-skin, or *corium*)	I. Skin nerves (*nervi cutanei*)	Sense of pressure Sense of warmth
	II. External sexual parts (*penis and clitoris*)	II. Sexual nerves (*nervi pudendi*)	3. Sexual sense
B. Sense-organs in which the terminal expansions of the nerves are distributed over inverted grooves of the outer skin-covering.	III. Mucous membrane of the mouth-cavity (tongue and palate)	III. Taste nerve (*nervus glossopharyngeus*)	4. Sense of taste
	IV. Mucous membrane of the nose-cavity	IV. Olfactory nerve (*n. olfactorius*)	5. Sense of smell
C. Sense-organs in which the terminal expansions of the nerves are distributed over vesicles separated from the external skin-covering.	V. Eye	V. Sight nerve (*n. opticus*)	6. Sense of sight
	VI. Ear	VI. Ear-nerve (*n. acousticus*)	7. Sense of hearing

Of the developmental history of the lower organs of sense I have but little to say. The development of the skin-covering, which is the organ of the sense of pressure (sense of touch) and of warmth, we have already traced (p. 209). I need only add that in the leather skin (*corium*) of Man, as of all higher Vertebrates, innumerable microscopic sense-organs develop, the direct relations of which to the sensations of pressure or resistance, of warmth and of cold, are not yet ascertained. These organs, in or upon which the sensitive skin-nerves terminate, are the so-called "touch bodies" and the "Pacinian bodies," named after their discoverer, Pacini. Similar bodies are also found in the organs of the sexual sense, in the penis of the male and in the clitoris of the female; these are processes of the integument, and the development of which we shall consider presently, in connection with that of the other organs of generation. The development of the organ of taste, the tongue and the palate, we will also consider presently, in connection with that of the intestinal canal, to which these parts belong. To one point, however, I will now call particular attention, viz., the mucous membrane of the tongue and palate, in which the taste-nerve terminates, is also in its origin a portion of the external skin-covering. For, as we found, the entire mouth-cavity originates, not as a part of the actual intestinal canal, but as a groove-like inversion of the external skin (vol. i. p. 338). Its mucous membrane, therefore, is formed, not from the intestinal layer, but from the skin-layer, and the taste-cells on the upper surface of the tongue and palate arise, not from the intestinal-glandular layer, but from the skin-sensory layer.

This is equally true of the mucous membrane of the organ of smell, the nose. The history of the development of this sense-organ is, however, of far higher interest. Although the human nose, externally viewed, seems simple and single, yet in Man, as in all higher Vertebrates, it consists of two perfectly distinct halves, of a right and a left nasal cavity. These two cavities are entirely separated by a vertical partition, so that the passage into the right nasal cavity lies only through the right nostril, and into the left cavity only through the left nostril. Posteriorly the two nasal cavities open separately through the two posterior nasal apertures into the head of the pharynx, so that the pharynx may be entered without touching the cavity of the mouth. This is the passage by which air is usually inhaled; the mouth being shut, it enters the pharynx, and thence passes through the windpipe into the lungs. Both nasal cavities are separated from the mouth-cavity by the horizontal bony palate roof, to the back of which the soft palate and the uvula is attached, like a hanging curtain. In the upper and hinder portion of both nasal cavities the olfactory nerve extends over the mucous membrane, which lines these parts. This is the first pair of brain nerves, which issue from the skull-cavity through the sieve bone. Its branches extend partly over the partition wall, and partly over the inner side-walls of the nasal cavities, to which are attached the "shells," or spongy bones of the nose—complex bony structures. These "shells" are much further developed in many of the higher Mammals than in Man. In all Mammals there are three of these "shells" in each of the two nasal cavities. The sensation of smell is produced by a current of air, containing odoriferous matters, passing over the mucous membrane of the cavities, and there coming in contact with nerve-ends.

The peculiar characters which distinguish the olfactory organ of Mammals from that of lower Vertebrates, are represented in Man. In all specific points the human nose exactly resembles that of the Catarhine Apes, some of which indeed possess an entirely human external nose (see face of the Nose-ape, Fig. 202, p. 175). The first rudiment of the olfactory organ in the human embryo does not, however, show any signs of the fine form of the future catarhine nose. Indeed, it first appears in the same form which persists for life in Fishes; in the form of two simple pits, or grooves in the skin of the upper surface of the head. In all Fishes two of these mere blind nose-pits are found in the upper surface of the head; sometimes they are situated at the back, near the eyes, sometimes near the snout, or, again, near the mouth-opening (Fig. 191, *n*, p. 113). They are lined by mucous membrane in folds, over which the end branches of the olfactory nerves spread.

In this its original condition the double nose of all Amphirhina (p. 101) is entirely unconnected with the primitive mouth-cavity. The connection, however, begins to appear even in some Primitive Fishes (*Selachii*); a superficial skin-furrow extends on each side from the nose-groove down to the adjacent corner of the mouth. This furrow, the nasal channel, or furrow (Fig. 231, *r*), is of great significance. In many Sharks (e.g., *Scyllium*) a special process of the frontal skin, the nasal flap, or "inner nasal process," overlaps the nasal furrow (*n*, *n'*). Opposite to this the outer edge of the furrow rises and forms the "outer nasal process." In Dipneusta and Amphibia these two nasal processes meet over the furrow and coalesce, thus forming a canal, the "nasal canal." There is now a passage from the external nasal groove through this canal directly into the mouth-

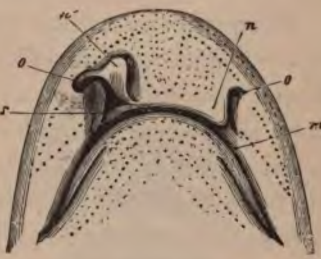


FIG. 231.—Head of a Shark (*Scyllium*), from the ventral side: *m*, mouth opening; *o*, nose grooves, or pits; *r*, nasal furrow; *n*, nose-flap in its natural position; *n'*, nose-flap turned up. (The dots are openings of mucous ducts.) (After Gegenbaur.)

cavity, which latter was developed independently of the groove. In the Dipneusta and the lower Amphibia the internal opening of the nasal canal lies well forward (behind the lips); in the higher Amphibia it lies further back. In the three highest vertebrate classes, the Amniota, the primary mouth-cavity is separated by the formation of the horizontal palate roof into two perfectly distinct cavities, the superior (or secondary) nasal cavity, and the inferior (or secondary) mouth-cavity. The nasal cavity is also separated by the vertical partition into two distinct halves, into a right and a left nasal cavity.

Comparative Anatomy thus still shows us simultaneously, in the ascending series of the double-nostrilled Vertebrates, from Fishes up to Man, all the various stages of development of the nose which the very highly developed olfactory organ of the higher Mammals has passed through *successively* in the different periods of its tribal history. The first rudiment of the organ of smell in the embryo of Man and in that of all the higher Mammals, makes its appearance in the same entirely simple form which is retained throughout life by the nose of Fishes. At a very early stage, and while no trace of the characteristic facial structure of Man is yet visible, a pair of small grooves appear on the front of the head, and before the primitive mouth-cavity; these were first discovered by Baer, and by him properly enough named "olfactory grooves" ("Riechgruben," Figs. 232, *n*, 233, *n*). These primitive nasal grooves are quite separate from the primitive mouth-cavity, or mouth indentation, which, as we found, likewise makes its appearance as a groove-like indentation of the external skin-covering, in front of the blind anterior extremity of the intestinal canal.

This pair of nasal grooves, as well as the single mouth groove (Fig. 235, *m*), is lined by the horn-plate. The

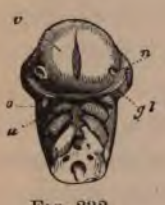


FIG. 232.

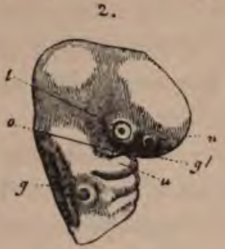


FIG. 233.

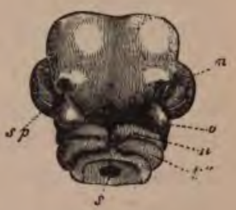


FIG. 234.

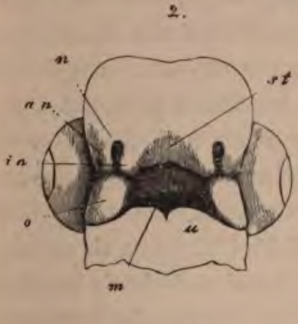


FIG. 235.

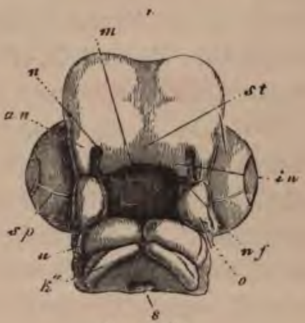


FIG. 236.

FIGS. 232, 233.—Head of an embryonic Chick, on the third day of incubation: 232, from the front; 233, from the right side. *n*, Nose-rudiment (olfactory grooves); *l*, eye-rudiment (sight-grooves); *g*, ear-rudiment (auditory grooves); *v*, fore-brain; *gl*, eye-slits; *o*, upper jaw process; *u*, lower jaw process of the first gill arch.

FIG. 234.—Head of an embryonic Chick, on the fourth day of incubation, from below: *n*, nose-groove; *o*, upper jaw process of the first gill arch; *u*, lower jaw process of the same; *k''*, second gill-arch; *sp*, choroidal fissure of the eye; *s*, throat (pharynx).

FIGS. 235, 236.—Two heads of embryonic Chicks: 235, at the end of the fourth day; 236, at the end of the fifth day of incubation. The letters as in Fig. 234. Additional letters are *in*, inner, and *an*, outer nasal process; *nf*, nasal furrow; *st*, frontal process; *m*, mouth-cavity. (After Koelliker.)

All these figures are proportionately enlarged.

original separation of the nasal groove from the mouth groove is, however, soon interrupted, for the frontal process (Fig. 235, *st*, Rathke's "Nasenfortsatz der Stirnwand") is immediately formed above the mouth groove. Right and left the edges of this process project in the form of two lateral processes: these are the inner nasal processes, or nasal flaps (Fig. 235, *in*). On each side, opposite to these rises a parallel ridge between the eye and the nasal groove. These ridges are the outer nasal processes (Rathke's "Nasendächer," Fig. 235, *an*). Between the inner and outer nasal process a channel-like depression thus extends on each side from the nose groove toward the mouth groove (*m*), and this channel is, of course, the same nasal furrow or channel which we found in the Shark (Fig. 231, *r*). As the two parallel edges of the inner and the outer nasal processes bend towards each other and coalesce above the nasal channel, the latter becomes a small tube—the primitive "nasal canal." In this stage of its Ontogeny, therefore, the nose of Man and of all other Amnion Animals consists of two small narrow tubes—the "nasal canals"—leading from the outer surface of the frontal skin into the simple primitive mouth-cavity. This transient condition resembles the permanent condition of the nose in Dipneusta and Amphibia. (Cf. Plate I., Frontispiece, with explanation.)

Specially significant in the modification of the open nasal channel into the closed nasal canal, is a plug-shaped formation, which extends from below up to the lower extremities of both the nasal processes on each side, and unites with them. This is the upper jaw process (Figs. 232, *o*, 236, *o*, Plate I., *o*). Below the mouth groove lie the gill arches, which are separated from one another by the gill openings

(Plates I., VI., and VII., *k*). The first of these gill arches, at present the most interesting to us, which we may call the jaw arch, develops the jaw-skeleton of the mouth (Plate I., *u*). A small process first grows out from the base of the front gill-arch: this is the upper jaw process. The first gill-arch itself develops a cartilage on its inner side, called after its discoverer, "Meckel's cartilage," on the outer surface of which the lower jaw forms (Figs. 232, *u*, 236, *u*). The upper jaw process forms the principal part of the entire framework of the upper jaw, viz., the palate bone and the wing bone. On its outer side the upper jaw bone, in the narrower sense, afterwards arises, while the middle portion of the upper jaw skeleton, the twixt jaw (intermaxillary bone) develops from the anterior portion of the frontal process. (See development of the face in Plate I.)

In the further characteristic development of the face in the three higher vertebrate classes, the two upper jaw processes are of the highest importance. From them proceeds the palate roof, the important horizontal partition which grows into the simple primitive mouth-cavity, separating it into two quite distinct cavities. The upper cavity, into which the two nasal cavities open, now develops into the nasal cavity—a respiratory air passage and an olfactory organ. The lower cavity, on the other hand, forms, by itself, the permanent secondary mouth-cavity (Fig. 237, *m*)—the digestive food passage and the organ of taste. Both the upper smell-cavity and the lower taste-cavity open at the back into the throat (*pharynx*). The palate roof, separating these two cavities, is formed by the coalescence of two lateral portions—of the horizontal plates of the two upper jaw processes (palate-plates; Fig. 237, *p*). When these do not perfectly adhere in the middle line, the result is a permanent longitudinal cleft, through which there is an open passage from the mouth-cavity directly into the nasal cavity. The so-called "wolf's jaws" are thus caused. The "hare-lip" and "split lip" is a slighter degree of this arrested development.[116]

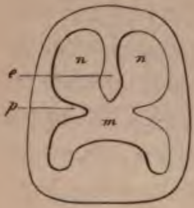
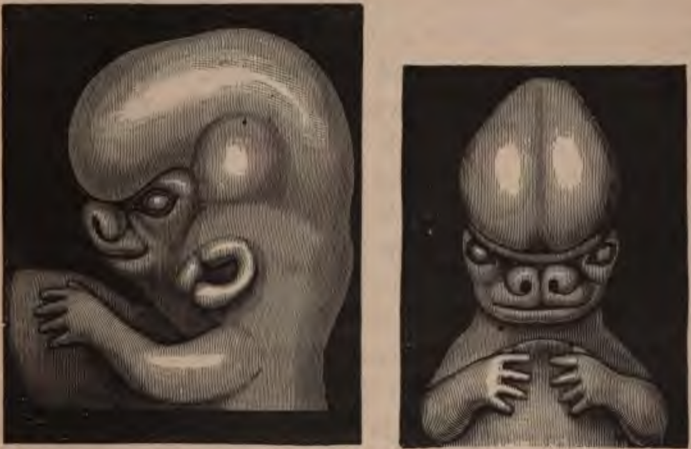


FIG. 237.—Diagrammatic transverse section through the mouth and nose cavity. While the palate-plates (*p*) separate the original mouth-cavity into the lower secondary mouth-cavity (*m*) and the upper nasal cavity, the latter is parted by the vertical partition wall of the nose (*e*) into two distinct halves (*n*, *n*). (After Gegenbaur.)

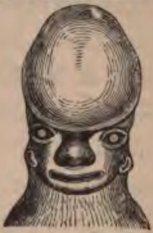
Simultaneously with the horizontal partition of the palate roof, a vertical wall by which the single nasal cavity is divided into two, a right and a left cavity, develops (Fig. 237, *n*, *n*). This vertical partition of the nose (*e*) is formed by the middle part of the frontal process: above this gives rise by ossification to the vertical lamella of the sieve bone (cubiform plate), and below the great vertical bony partition wall—the "plough-share" (*vomer*), and in front to the twixt-jaw (*os intermaxillare*). Goethe was the first to show that in Man, just as in all the other Skulled Animals, the twixt-jaw appears as an independent bone between the two halves of the upper jaw. The vertical partition wall of the nose finally coalesces with the horizontal palate roof. The two nasal cavities are now as entirely separate from one another as from the secondary mouth-cavity. These three cavities open, however, at the back into the pharnyx, or jaw-cavity.

The double-nostrilled nose has now attained the structure characteristic of Man in common with all other Mammals. Its further development is very easily intelligible: it is limited to the formation of internal and external processes of the walls of both nasal cavities. Within the cavities develop the "nose shells," spongy bony structures, over which the olfactory mucous membrane spreads. The first brain nerve, the olfactory nerve, with its delicate branches, passes



FIGS. 238, 239.—Upper part of the body of a human embryo (16 mm. in length) during the sixth week: Fig. 238, from the left side; Fig. 239, from the front. The origin of the nose in two lateral halves, originally separate, is still plainly visible. The nose and upper lip are disproportionately great in comparison with the rest of the face, especially with the lower lip. (After Kollman.)

FIG. 240.—Face of a human embryo of eight weeks. (After Ecker.) Cf. Frontispiece, Plate I. Fig. MI—MIII.



from the large brain through the roof of both nasal cavities into the cavities, and extends over the olfactory mucous membrane. At the same time, by inversion of the nasal mucous membrane, the minor cavities of the nose, which are afterwards filled with air, and which communicate directly with the two nasal cavities, arise (frontal cavities, cavities of the sphenoid bone, jaw cavities, etc.). In this special stage of development they occur only in Mammals.[171]

The external nose is not developed until long after all these essential internal parts of the olfactory organ have been formed. The first trace in the human embryo appears at the end of the second month (Figs. 238–240). Any human embryo during the first month shows that originally there is no trace of the external nose. It afterwards grows out from the anterior nasal portion of the primitive skull. The form of nose which is characteristic of Man does not appear till a period far later. Much stress is usually laid on the shape of the external nose as a noble organ, occurring exclusively in Man; but there are Apes which have very human noses, as, for instance, the Nosed Ape already mentioned. On the other hand, the external nose, the fine shape of which is so extremely important to the beauty of the facial structure, possesses in certain inferior races of Man a shape anything but beautiful. In most Apes the external structure of the nose remains undeveloped. Especially remarkable is the important fact already cited that it is only in the Apes of the Old World, in the Catarhines, that the nasal partition wall (*septum*) remains as small as it is in Man; in Apes of the New World it widens considerably at the base, so that the nostrils open outwards (Platyrhini, p. 175).

TABLE XXX.

Systematic Survey of the Chief Phylogenetic Stages of the Human Nose.

First Stage: Nose of the earlier Primitive Fishes.

The nose is formed by a pair of simple skin-grooves (nose-pits) in the outer surface of the head (like those which are now permanently retained by the lower Selachians).

Second Stage: Nose of the more recent Primitive Fishes.

Each of the two blind nasal grooves becomes connected by a furrow (nasal-furrow) with one end of the mouth (as is yet permanently the case in the higher Selachians).

Third Stage: Nose of the Dipneusta.

The two nasal furrows change, in consequence of the coalescence of their edges, into closed canals (primary nose-canals), which open at their front ends, within the soft edges of the lip, into the primary mouth-cavity; as is yet permanently the case in the Dipneusta and the earlier lower Amphibia (*Sozobranchia*).

Fourth Stage: Nose of Amphibia.

The inner openings of the nasal canals penetrate further back into the primary mouth-cavity, so that they are surrounded by hard bony portions of the jaw (as is yet permanently the case in the higher Amphibia).

Fifth Stage: Nose of the Protamnia.

The primitive mouth-cavity, into which both nasal canals open, separates, in consequence of the formation of a horizontal partition (the palate-roof), into an upper nasal cavity and a lower (secondary) mouth-cavity. The formation of the spongy bones of the nose commences (as in the earlier Amnion Animals).

Sixth Stage: Nose of the earlier Mammals.

The simple nose-cavity separates, in consequence of the development of a vertical partition wall (the "plough," *vomer*), into two distinct nose-cavities, each of which is occupied by one of the nasal canals (as is yet the case in all Mammals). The spongy nose-bones differentiate.

Seventh Stage: Nose of the more recent Mammals.

Within both nose-cavities the development of the spongy bones proceeds further, and an external nose begins to form.

Eighth Stage: Nose of the Catarhine Apes.

The internal and the external nose attain the full development exclusively characteristic of Catarhine Apes and of Man.

The history of the development of the eye is equally remarkable and instructive. For although the eye, owing to its exquisite optical arrangement and wonderful structure, is one of the most complex and most nicely adapted organs, yet it develops, without a preconceived design, from a very simple rudiment in the outer skin-covering.

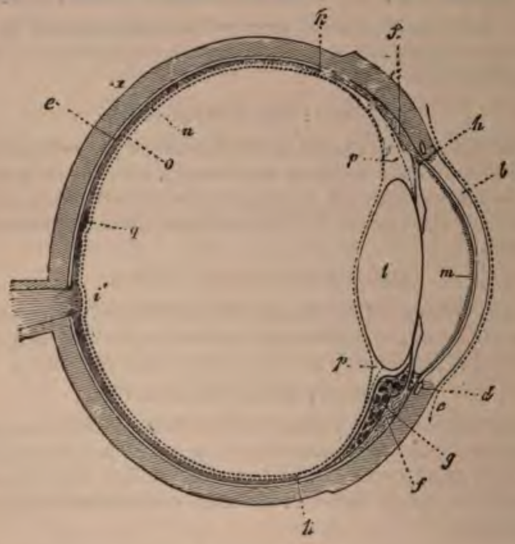


FIG. 241.—The human eye in transverse section: *a*, protective membrane (*sclerotica*); *b*, horn membrane (*cornea*); *c*, outer membrane (*conjunctiva*); *d*, circular veins of iris; *e*, vascular membrane (*choroidea*); *f*, ciliary muscle; *g*, *corona ciliaris*; *h*, rainbow membrane (*iris*); *i*, optic nerve (*n. opticus*); *k*, anterior limit of the retina; *l*, crystalline lens (*lens crystallina*); *m*, inner cover of the horn membrane (water membrane, *membrana Descemeti*); *n*, pigment membrane (*pigmentosa*); *o*, *retina*; *p*, "*petits*-canal;" *q*, yellow spot of the *retina*. (After Helmholtz.)

When fully developed, the human eye is a globular capsule (the eyeball, *bulbus*, Fig. 241). This lies in the bony orbit of the skull, surrounded by protective fat and by motor muscles. The greater part of this eyeball is occupied by a semi-fluid, clear gelatinous substance, the vitreous body (*corpus vitreum*). The crystalline lens (Fig. 241, *l*) is embedded in the anterior surface of the vitreous body. It is a lentil-shaped, bi-convex, transparent body—the most important of the light-refracting media of the eye. Among these media is, in addition to the lens and vitreous body, the aqueous humour (*humor aqueus*, at *m*, in Fig. 241), in front of the lens. These three pellucid, light-refracting media—the vitreous body, the crystalline lens, and the aqueous humour—by which the rays of light, incident on the eye, are refracted and concentrated, are enclosed in a firm globular capsule consisting of several different membranes, comparable with the concentric layers of an onion. The outer and thickest of these forms the white protective membrane of the eye (*sclerotica*, *a*). It consists of firm, compact white connective tissue. In front of the lens a circular, very convex, transparent plate, resembling a watch glass, is inserted in the white protective membrane; this is the horny membrane (*cornea*, *b*). On its outer surface the horny membrane is covered by a very thin coating of outer skin (*epidermis*); this coating is called the connecting membrane (*conjunctiva*); it extends from the horny membrane over the inner surface of both eyelids—the upper and lower folds of skin which on closing the eyes are drawn together over them. At the inner corner of our eye there is, as a sort of rudimentary organ, the remnant of a third (inner) eyelid, which, as the "nictitating membrane," is highly developed in the lower Vertebrates (vol. i. p. 110). Below the upper eyelid are lodged the tear-glands, the secretion of which keeps the surface of the eye smooth and clean.

Directly under the protective membrane is a delicate dark-red, highly vascular membrane, the vascular membrane (*choroidea, e*), and within this the retina (*o*), which is a dilatation of the optic nerve (*i*). This latter is the second brain nerve. It extends from the "centre of sight" (the second brain-bladder) to the eye, penetrates the outer coats of this, and then extends, as the retina, between the vascular membrane (*choroidea*) and the vitreous body (*corpus vitreum*). Between the retina and the vascular membrane lies another very delicate membrane, which is commonly, but wrongly, considered as part of the latter. This is the black pigment membrane (*pigmentosa, lamina pigmenti, n*), or the "black carpet" (*tapetum nigrum*). It consists of a single layer of beautiful hexagonal cells accurately joined together and filled with black pigment granules. This pigment membrane lines, not only the inner surface of the actual vascular membrane, but also the posterior surface of its anterior muscular prolongation, which, as a circular ring-like membrane, covers the edge of the lens, and prevents the penetration of lateral rays. This is the well-known "rainbow membrane" (*iris, h*), which is differently coloured in different persons (blue, gray, brown, etc.). This "rainbow membrane" is the limit towards the front of the vascular membrane. The round hole in the iris is the pupil, through which the rays of light pass into the interior of the eye. Where the iris proceeds from the edge of the actual vascular membrane, the latter is much thickened and forms a beautiful ciliated crown (*corona ciliaris, g*), which surrounds the edge of the lens with about seventy large, and many smaller rays.

In the embryo of Man, as in that of all other Amphirhina, two pear-shaped vesicles grow out laterally, at a very early period, from the foremost part of the first brain bladder (Fig. 223, *a*, p. 218). These bladder-like protuberances are the primary eye-vesicles. At first they are directed outward and forward, but they soon make their way further downward, so that after the specialization of the five brain-bladders, they lie at the base of the twixt-brain. The internal spaces within the two pear-shaped vesicles, which soon attain a considerable size, communicate through their hollow stalks with the cavity of the twixt-brain. Their outer covering is formed by the outer skin-covering (horn-plate and leather-plate). Where, on each side, the latter comes directly in contact with the most curved portion of the primary eye-vesicles, a thickening (*l*) arises, and at the same time a groove-like indentation (*o*) in the horn-plate (Fig. 242, 1). This groove, which we will call the lens groove, changes into a closed sac, the thick-walled lens vesicle (2, *l*), owing to the fact that the edges of the groove coalesce above

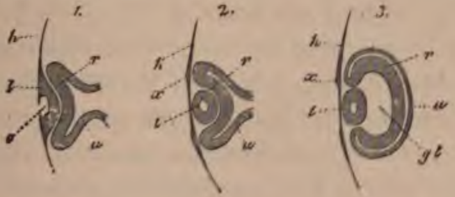


FIG. 242.—Eye of an embryonic Chick in longitudinal section (1, of a germ after sixty-five hours of incubation; 2, of a somewhat older germ; 3, of a germ four days old): *h*, horn-plate; *o*, lens groove; *l*, lens (in 1, it still forms part of the epidermis, while in 2 and 3 it has separated); *x*, thickening of the horn-plate at the point from which the lens separated; *gl*, vitreous body; *r*, retina; *u*, pigment membrane. (After Remak.)

it. Exactly as the medullary tube originally separates from the outer germ-layer does this lens-sac separate from the horn-plate, in which it originated. The space within this sac is afterwards entirely filled by the cells of its thick wall, and the solid crystalline lens is thus formed. The latter is, therefore, purely a formation of the epidermis. Together with the lens the small fragment of the leather-plate (*corium*) lying below the lens separates from the outer skin-covering. This small piece of the leather-skin very soon forms a highly vascular sac round the lens (*capsula vasculosa lentis*). Its anterior portion at first covers the pupillary orifice, and is then known as the pupillary membrane (*membrana pupillaris*). Its back portion of the same membrane is called the "*membrana capsulo-pupillaris*." This "vascular lens capsule, which merely serves to nourish the growing lens," afterwards entirely disappears. The later, permanent lens capsule contains no vessels, and is a structureless secretion of the lens cells.

As the lens thus separates from the horn-plate and grows inward, it must necessarily indent the adjoining primary eye-vesicles from without (Fig. 242, 1–3). This process may be compared to the inversion of the germ-membrane vesicle (*blastula*), which in the Amphioxus and in many low animals gives rise to the gastrula (vol. i. p. 192). In both instances the inversion of one side of the closed vesicle proceeds until finally the inner, inverted portion touches the outer, uninverted portion of the wall of the vesicle, so that the cavity disappears. Just as in the gastrula the former part changes into the intestinal layer (*entoderma*), and the latter into the skin-layer (*exoderma*), so in the inverted primary eye-vesicle the retina develops from the former (inner) part (Fig. 242, *r*), and the black pigment membrane (*w*) from the latter (the outer, uninverted part). The hollow stalk of the primary eye-vesicle changes into the optic nerve.

The lens (*l*) which enacts so important a part in this inverting process of the primary eye-vesicle, lies at first directly upon its inverted part, that is, on the retina (*r*). Very soon, however, the two separate, a new body, the vitreous body (*corpus vitreum, gl*), coming in between them. While the lens-sac is detaching itself, and the primary eye-vesicle is being inverted from without, another inversion simultaneously proceeds from beneath—from the superficial portion of the skin-fibrous layer, *i.e.*, from the leather-plate of the head. At the back of the lens and below it, a ledge-like process of the leather-plate arises (Fig. 243, *g*), which inverts the primary eye-vesicle (now shaped like a cup) from below, and presses in between the lens (*l*) and the retina (*r*) Thus the primary eye-vesicle assumes the form of a hood. The opening of this hood, answering to the face, is covered by the lens; but the opening, through which the neck would pass, answers to the indentation through which the leather-skin passes in between the lens and the retina (the inner wall of the hood). The space within this secondary eye-vesicle is almost filled by the vitreous body, which answers to the head wrapped in this hood. The hood itself is, properly speaking, double: the inner hood itself is the retina, and the outer one, directly surrounding the former, is the pigment membrane. The comparison with a hood renders this process of inversion, which is sometimes hard to explain, more clearly understood. The rudiment of the vitreous body (*corpus vitreum*) is at first very inconsiderable (Fig. 243, *g*), and the retina disproportionally thick. As the former expands, the latter becomes much thinner, till at last the retina appears only as a very delicate coat of the thick, almost globular vitreous body, which fills the greater part of the secondary eye-vesicle. The outer layer of the vitreous body changes into a highly vascular capsule, the vessels of which afterwards disappear.

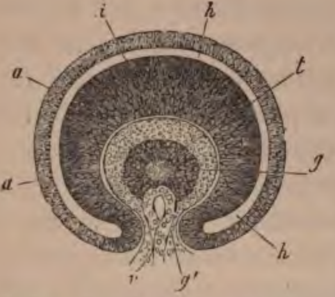


FIG. 243.—Horizontal transverse section through the eye of a human embryo of four weeks; 100 times enlarged (after Koelliker): *t*, lens (the dark wall of which is equal to the diameter of the central cavity); *g*, vitreous body (connected with the leather-plate by a stalk, *g′*); *v*, vascular loop (penetrating through the stalk (*g′*) into the vitreous body behind the lens); *r*, retina (inner, thicker, inverted lamella of the primary eye-vesicle); *a*, pigment membrane (outer, thinner, uninverted lamella of the same); *h*, intermediate space between the retina and the pigment membrane (remnant of the cavity of the primary eye-vesicle).

The slit-like passage through which the rudiment of the vitreous body grows from below in between the lens and the retina, of course causes a break in the retina and the pigment-membrane. This break, which appears on the inner surface of the vascular membrane as a colourless streak, has been inaptly called the choroidal cleft, though the true vascular membrane is not cleft at all at this point (Fig. 234, *sp*, 235, *sp*, p. 243). A thin process of the vitreous body passes inward on the under surface of the optic nerve, which it inverts in the same way as the primary eye-vesicle was inverted. The hollow cylindrical optic nerve (the stalk of the primary eye-vesicle) is thus transformed into a channel, opening downward. The inverted lower surface attaches itself to the uninverted upper surface of the hollow stalk, so that the hollow space within the stalk, forming the communication between the cavity of the twixt-brain and of the primary eye-vesicle, now disappears. The two edges of the channel now grow downward toward each other, enclose the band-like process of the leather-plate, and coalesce beneath it. Thus this process now lies within the axis of the solid secondary optic nerve. It develops into a cord of connective tissue carrying the central blood-vessel of the retina (*vasa centralia retinæ*).

An entirely fibrous covering, the fibrous capsule of the eye, now finally forms round the outside of the secondary eye-vesicle and its stalk (the secondary optic nerve). It originates from the head-plate, from that part of the skin-fibrous layer which immediately encloses the eye-vesicle. This fibrous covering takes the form of a completely-closed globular sac, which surrounds the whole ball of the eye, and on the outer side of this, grows in between the lens and the horn-plate. The globular wall of the capsule soon separates, by fission of the surface, into two distinct membranes. The inner membrane becomes the choroidea, or vascular layer; in front it forms the ciliated crown (*corona ciliaris*) and the iris. The outer membrane, on the other hand, becomes the white enveloping, or protective membrane (*sclerotica*), and, in front, forms the transparent horny membrane (*cornea*). The rudiments of all the essential parts of the eye are now formed, and its further development is only in details, in the complex differentiation and combination of the several parts.

TABLE XXXI.

Systematic Survey of the Development of the Human Eye.

I. Systematic Survey of those parts of the Human Eye which develop from the first of the Secondary Germ-layers, the Skin-sensory Layer.

A. Products of the **Marrow-plate**	1. Stem of the primary eye-vesicle	1. Optic nerve	*Nervus opticus*
	2. Inner (inverted) part of the primary eye-vesicle	2. Retina	*Retina*
	3. Outer (uninverted) part of the primary eye-vesicle	3. Screen, or pigment-coat	*Pigmentosa (lamina pigmenti)*
B. Products of the **Horn-plate**	4. Vesicle separated from the horny plate	4. Crystalline lens	*Lens crystallina*
	5. Outer epidermic skin	5. Connective membrane	*Conjunctiva*
	6. Inverted portions of the epidermic skin	6. Tear-glands	*Glandulæ lacrymales*

II. Systematic Survey of those parts of the Human Eye which develop from the second of the Secondary Germ-layers, the Skin-fibrous Layer.

C. Products of the **Leather-plate**	7, 8. Ledge-like process of the corium on the lower side of the primary eye-vesicle	7. Vitreous body 8. Vascular membrane of the vitreous body	*Corpus vitreum* *Capsula vasculosa corporis vitrei*
	9. Continuation of the corium process	9. Central vessels of the retina	*Vasa centralia retinæ*
	10. Pupillary membrane, with its capsule	10. Vascular membrane of the lens	*Capsula vasculosa lentis crystallinæ*
	11. Folds of the leather skin (*corium*)	11. Eyelids	*Palpebræ*
D. Products of the **Skull-plate**	12, 13. Vascular membrane of the eyeball (*capsula vasculosa bulbi*))	12. Vascular membrane 13. Rainbow membrane	*Choroidea* *Iris*
	14, 15. Fibrous membrane of the eyeball (*capsula fibrosa bulbi*)	14. Protective membrane 15. Horny membrane	*Sclerotica* *Cornea*

The most important fact in this remarkable process of eye-development is the circumstance that the optic nerve, the retina, and the pigment-membrane originate from a part of the brain, from a protuberance of the twixt-brain, while the crystalline lens, the most important refracting medium, develops from the outer skin (*epidermis*). From the outer skin—the horny lamina—originates also the delicate connecting membrane (*conjunctiva*) which afterwards envelopes the outer surface of the eyeball. The tear-glands proceed, as branched processes, from the conjunctiva (Fig. 214, p. 202). All the other parts of the eye originate from the skin-fibrous layer; the vitreous body and the vascular lens-capsule from the leather-plate, the choroid coat with the iris, and the protective membrane (*sclerotica*) with the horny membrane (*cornea*) from the head-plates.

The outer protective organs for the eye, the eyelids, are merely simple folds of skin, which, in the human embryo, appear in the third month. In the fourth month the upper eyelid adheres to the lower, and the eye then remains covered by them till birth. (Plate VII. Fig. *M* III., *R* III., etc.) The two eyelids usually again separate shortly before birth, but sometimes not till after. Our skulled ancestors had, in addition to these, a third eyelid, the nictitating membrane, which was drawn over the eye from the inner corner. Many Primitive Fishes (*Selachii*) and Amnion Animals yet retain this. In Apes and in Man it has atrophied, and only a small remnant of it exists in the inner corner of the eye as the "crescent-shaped fold," as a useless "rudimentary organ." (Cf. vol. i. p. 109.) Apes and Man have also lost the "Harder gland," opening below the nictitating membrane, which appears in other Mammals, and in Birds, Reptiles, and Amphibians.

The ear of Vertebrates develops in many important points similarly to the eye and nose, but yet in other respects very differently.[172] The organ of hearing of the developed human being resembles that of other Mammals in all essential particulars, and is especially similar to that of Apes. As in the latter, it consists of two principal parts, an apparatus for the conveyance of sound (external and middle ear) and an apparatus for producing the sensation of sound (internal ear). The outer ear opens in the ear-shell (*concha*

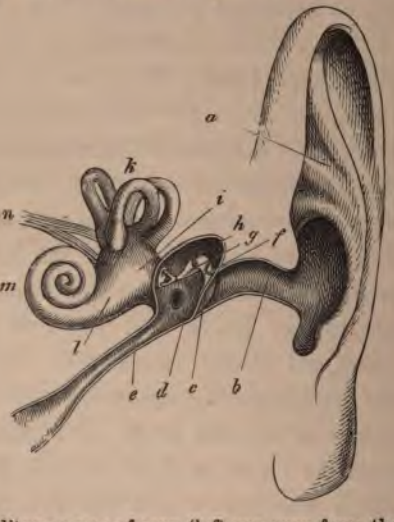


FIG. 244.—Auditory organ of man (left ear, seen from the front; natural size): *a*, ear-shell: *b*, external ear-canal; *c*, drum, or tympanic membrane; *d*, cavity of drum; *e*, ear-trumpet; *f*, *g*, *h*, the three ear bonelets (*f*, hammer; *g*, anvil; *h*, stirrup); *i*, ear-pouch (*utriculus*); *k*, the three semi-circular canals; *l*, ear-sac (*sacculus*); *m*, snail (*cochlea*); *n*, auditory nerve.

auris), situated at the side of the head (Fig. 224, *a*). From this the outer ear-canal, which is usually about an inch long, leads to the inside of the head (*b*). The inner end of this tube is closed by the well-known tympanic membrane or drum (*tympanum*); a thin membrane of oval form (*c*), placed in a vertical position, but slightly inclined. This membrane separates the outer ear-canal from the so-called cavity of the drum (*cavum tympani*). This is a small cavity enclosed in the petrous part of the temporal bone, which is filled with air and connected by a special tube with the mouth-cavity. This tube is somewhat longer, but much narrower than the outer ear-canal; it leads inward and forward in an oblique direction from the inside wall of the tympanum and opens behind the inner nostrils (or Choana) into the upper part of the cavity of the throat (*pharynx*). This canal is called the Eustachian tube (*tuba Eustachii*). It equalizes the pressure of the air in the tympanic cavity, and the outer atmospheric air which enters by the ear canal. Both the Eustachian tube and the tympanic cavity are lined by a thin, mucous membrane, which is a direct continuation of the mucous membrane of the throat. Within the tympanic cavity are the three bonelets of the ear, which, from their characteristic shape, are called the hammer, the anvil, and the stirrup (Fig. 244 *f*, *g*, *h*). The hammer (*f*) lies furthest outward, just within the tympanic membrane; the anvil (*g*) is wedged in between the two others, above the hammer, and further in than the hammer; and, lastly, the stirrup (*h*) lies next to the anvil toward the inside, and touches with its base the outer wall of the internal ear, or the auditory sac. All these parts of the middle and external ear belong to the sound-conducting apparatus. Their principal office is to convey the waves ot sound from without through the thick side-wall of the head, to the internal ear. In Fishes these parts are entirely unrepresented. In them, the sound-waves are conveyed directly through the wall of the head itself to the internal ear.

The inner apparatus, that which produces the sensation of sound, receiving the sound-waves thus conveyed to it, consists in Man, as in all other Vertebrates (with the single exception of the Amphioxus), of a closed auditory sac filled with fluid, and of an auditory nerve, the ends of which are distributed over the wall of this sac. The vibrations of the waves of sound are conveyed by that medium to these nerve-ends. In the auditory fluid (*endolymph*), which fills the labyrinth, and opposite the places at which the auditory nerves enter, are some small stones, composed of a mass of microscopic calcareous crystals (*otoliths*). The organs of hearing of most Invertebrates have essentially the same construction. In them, also, it usually consists of a closed sac filled with fluid, containing otoliths, and having the auditory nerve distributed over its wall. But while in Invertebrates the auditory vesicle is usually of a very simple spherical or oval form, in all Amphirhina, on the contrary, that is, in all Vertebrates above the Fishes up to Man, it is distinguished by a very characteristic and singular form known as the auditory labyrinth. This thin membranous labyrinth is enclosed in a bony envelope of the same form, the osseous labyrinth (Fig. 245), which lies within the petrous bone of the skull. The labyrinth in all Amphirhina is divided into two sacs. The larger sac is called the auditory pouch (*utriculus*), and has three curved appendages, called the semi-circular canals (*c*, *d*, *e*); the smaller sac is called the auditory sac (*sacculus*), and is connected with a peculiar appendage, which in Man and the higher Mammals is distinguished by a spiral form, like the shell of a snail, and hence is called the "snail" (*cochlea, b*). On the thin wall of this delicate membranous labyrinth, the auditory nerve, which passes from the after-brain to the labyrinth, is distributed in a very complex manner. It divides into two main branches, the nerve of the cochlea, and the nerve of vestibule, for the remaining part of the labyrinth. The former seems specially to determine the quality of the sound heard, the latter its quantity. The nerve of the cochlea tells us the pitch and quality of sounds, the nerve of the vestibule their strength.

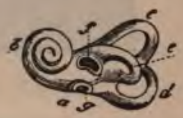
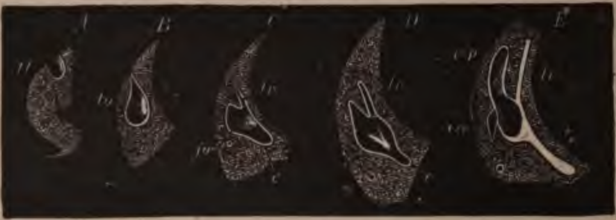
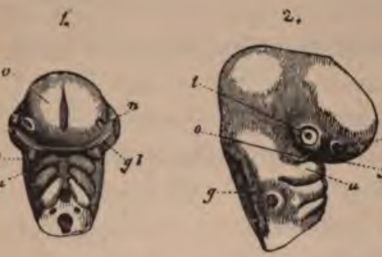


FIG. 245.—The bony labyrinth of the human ear (left side): *a*, vestibule; *b*, cochlea; *c*, upper semi-circular canal; *d*, posterior semi-circular canal; *e*, outer semi-circular canal; *f*, *fenestra ovalis*; *g*, *fenestra rotunda*. (From Meyer.)

The first rudiment of this extremely complex organ of hearing is very simple in the human embryo, as in those of all other Skulled Animals (*Craniota*); it is a groove-like depression of the outer skin (*epidermis*). At the back of the head, near the after-brain, at the upper end of the second gill-opening, a little wart-like thickening of the horn-plate arises on each side (Figs. 246, *A*, *fl*; 248, *g*). This deepens into a small groove, and separates from the outer-skin, just as does the lens of the eye. (Cf. p. 253.) A small vesicle filled with fluid, the primitive ear-vesicle, is thus formed on each side, immediately below the horn-plate of the back part of the head; this is also called the "primary labyrinth" (Plates VI. and VII.). As this separates from its original site, the horn-plate, and grows inward and downward in the skull, it changes from a globular to a pear-shaped form (Figs. 246, *B*, *lv*; 249, *o*). The outer part has elongated into a thin stalk, which at first opens outward in a narrow canal. (Cf. Fig. 137, *f*, vol. i. p. 382.) This is called the appendage of the labyrinth *recessus labyrinthi*, Fig. 246, *lr*).





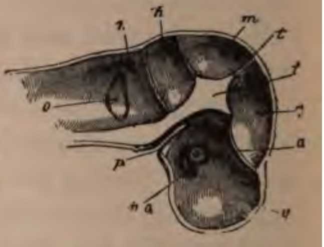


FIG. 246.—Development of the ear-labyrinth of a Chick, in five consecutive stages (*A–E*) (cross-sections through the rudimentary skull): *fl*, ear-groove; *lv*, ear-vesicle; *lr*, labyrinth appendage; *c*, rudiment of the cochlea; *csp*, hind semi-circular canal; *cse*, outer semi-circular canal; *jr*, jugular vein. (After Reissner.)

FIGS. 247, 248.—Head of an embryonic Chick, on the third day of incubation: 247 in front, 248 from the right; *n*, rudimentary nose (olfactory groove); *l*, rudimentary eye (ocular groove); *g*, rudimentary ear (auditory groove); *v*, fore-brain; *gl*, eye-slit; *o*, process of the upper jaw; *u*, process of the lower jaw of the first gill-arch. (After Koelliker.)

FIG. 249.—Primitive brain of human embryo of four weeks, in vertical section, and the left half observed from within: *v*, *z*, *m*, *h*, *n*, the five grooves of the skull cavity in which the five brain bladders are situated (fore, twixt, mid, hind, and after brains); *o*, primary, pear-shaped auditory vesicle (showing through); *a*, eye (showing through); *no*, optic nerve; *p*, canal of the hypophysis; *t*, central skull-pieces. (From Koelliker.)

In lower Vertebrates, this develops into a peculiar cavity filled with calcareous crystals, which in some Primitive Fishes (*Selachii*) remains permanently open, and opens above on the skull (*ductus endolymphaticus*). In Mammals, on the contrary, the appendage of the labyrinth atrophies. In these, it is of interest only as a rudimentary organ, which has no longer any physiological significance. Its useless remnant traverses the osseous wall of the petrous bone in the form of a narrow canal, and is called the aqueduct of the vestibule (*aquæductus vestibuli*).

Only the inner and lower part (extended like a bladder) of the detached ear-vesicle develops into the differentiated and extremely complex structure which is afterwards known as the "secondary labyrinth." This vesicle separates at a very early stage into an upper, larger section, and a lower, smaller section. The former gives rise to the ear-pouch (*utriculus*) with the three semi-circular canals; from the latter proceeds the ear-sac (*sacculus*) with the "snail" (*cochlea*, Fig. 246, *c*). The three semi-circular canals originate as simple pocket-like processes from the ear-pouch (Fig. 246, *E*, *cse* and *csp*). In the centre of each of these processes, the two walls coalesce, and separate themselves from the utricle, while their extremities still communicate with its cavity. In all Double-nostrils (*Amphirhina*) there are three semi-circular canals, as in Man, while of the Cyclostomi the Lampreys have but two, and the Myxinoides but one (p. 103). The highly-developed structure of the "snail" (*cochlea*), which is one of the most delicate and admirable products of adaptation in the mammalian body, originally develops very simply as a bottle-like process from the ear-sac (*sacculus*). As Hasse has shown, the various stages in its ontogenetic development still exist permanently side by side in the ranks of the lower Vertebrates.[173] Even in Monotremes the snail-like spiral curving of the cochlea is not present; it is exclusively characteristic of the other Mammals and Man.

The auditory nerve (*nervus acusticus*), or the eighth brain-nerve,—one of the main branches of which distributes itself over the "snail" (*cochlea*), the other over the other parts of the labyrinth,—is, as Gegenbaur has shown, the sensory dorsal branch of a spinal brain-nerve, the motor ventral branch of which is the motor nerve of the facial muscles (*nervus facialis*). Phylogenetically it has, therefore, originated from an ordinary skin-nerve, and is, consequently, of wholly different origin from the optic and olfactory nerves, which represent the two direct processes of the brain. In this respect the organ of hearing differs essentially from the organs of sight and of smell. The auditory nerve originates from the cells of the head-plate; therefore, from the skin-fibrous layer. From this also develop all the membranous, cartilaginous, and bony coverings of the ear-labyrinth.

The development of the apparatus for the conveyance of sound, situated in the middle and external ear of Mammals, is entirely distinct from that of the apparatus of auditory sensation. It must be regarded, phylogenetically as well as ontogenetically, as an independent, secondary formation, which only afterwards connects itself with the primary internal ear. Its development is, however, not less interesting, and is equally clearly explained by Comparative Anatomy. In all Fishes, and in the yet lower Vertebrates, there is no special apparatus for the conveyance of sound,

TABLE XXXII.

SYSTEMATIC SURVEY OF THE CHIEF STAGES IN THE DEVELOPMENT OF THE HUMAN EAR.

I. *First Stage.*

The auditory nerve is an ordinary sensitive skin-nerve, which, during the differentiation of the horn-plate, appears at a certain point on the skin of the head.

II. *Second Stage.*

The differentiated place of the horn-plate, at which the auditory nerve appeared, forms a small special auditory groove in the skin, which has an outer orifice in the appendage called the "labyrinth."

III. *Third Stage.*

The auditory groove has detached itself from the horn-lamina, and forms a small closed auditory vesicle filled with fluid. The "labyrinth-appendage" becomes rudimentary (*Aquæductus vestibuli*).

IV. *Fourth Stage.*

The auditory vesicle differentiates into two connected parts, the ear-pouch (*utriculus*) and the ear-sac (*sacculus*). Each of the two vesicles receives a special main branch of the auditory nerve.

V. *Fifth Stage.*

Three semi-circular canals grow from the ear-pouch (as in all *Amphirhina*).

VI. *Sixth Stage.*

The "snail" (*cochlea*) grows from the ear-sac in Fishes and Amphibia; it is very insignificant, and is only developed as an independent part in the Amniota.

VII. *Seventh Stage.*

The first gill-opening (the blow-hole of Selachians) changes into the tympanic cavity and the Eustachian tube; the former is externally closed by the tympanic membrane (Amphibia).

VIII. *Eighth Stage.*

The small bones of the ear (*ossicula auditus*) (the hammer (*malleus*) and anvil (*incus*) from the first gill-arch, the stirrup (*stapes*) from the second) develop from parts of the first and second gill-arches.

IX. *Ninth Stage.*

The external ear is developed, together with the bony ear-canal. The shell of the ear is pointed and movable (as in most lower Mammals).

X. *Tenth Stage.*

The ear-shell, with its muscles, becomes disused and a rudimentary organ. It is no longer pointed, but, on the contrary, has a curved rim with a small ear-flap (as in Anthropoid Apes and Men).

TABLE XXXIII.

Systematic Survey of the Development of the Human Ear.

I. Survey of the parts of the Internal Ear. (Apparatus perceptive of sound.)

A. Products of the **Horn-plate**	1. Stalk of the primary ear-vesicle	1. Aqueduct of the vestibule (*Ductus endolymphaticus*)	*Aquæductus vestibuli s. Recessus labyrinthi*
	2, 3. Upper part of the primary ear-vesicle	2. Ear-pouch 3. Three semi-circular, or curved canals	*Utriculus* *Canales semi-circulares*
	4, 5. Lower part of the primary ear-vesicle	4. Ear-sac 5. "The snail"	*Sacculus* *Cochlea*
B. Products of the **Head-plate**	6. Auditory nerve	6. Auditory nerve	*Nervus acusticus*
	7. Bony covering of the membranous labyrinth	7. Osseous labyrinth	*Labyrinthus osseus*
	8. Bony covering of the whole internal ear	8. "The stony bone"	*Os petrosum*

II. Survey of the parts of the Intermediate and External Ear. (Apparatus for the conveyance of sound.)

C. Products of the first **Gill-opening**	9. Inner part of the first gill-opening	9. Eustachian tube	*Tuba Eustachii*
	10. Central part of the first gill-opening	10. Tympanic cavity (Interior of the drum)	*Cavum tympani*
	11. Closed part of the first gill-opening	11. Tympanic membrane (Head of the drum)	*Membrana tympani*
D. Products of the first two **Gill-arches**	12. Upper part of the second gill-arch	12. Stirrup (First bonelet of the ear)	*Stapes*
	13. Upper part of the first gill-arch	13. Anvil (Second bonelet of the ear)	*Incus*
	14. Central part of the first gill-arch	14. Hammer (Third bonelet of the ear)	*Malleus*
E. Product of the **Head-plate**	15. Tympanic circle (*Annulus tympanicus*)	15. Bony outer auditory passage	*Meatus auditorius osseus*
F. Product of the **Skin-covering**	16. Circular membranous fold at the closed part of the first gill-opening	16. Ear-shell	*Concha auris*
		17. Rudimentary ear-muscles	*Musculi conchæ*

no external and middle ear; in these animals there is only a labyrinth, an internal ear, situated within the skull. The tympanic membrane, its cavity, and all the connected parts are unrepresented. The middle ear first develops in the Amphibian class, in which a tympanic membrane, a tympanic cavity, and an Eustachian tube are first found. All these essential parts of the middle ear develop from the first gill-opening, with its surrounding parts, which in the Primitive Fishes (*Selachii*) remains through life as an open blow-hole, situated between the first and second gill-arches. In the embryos of higher Vertebrates it closes in the centre, the point of concrescence forming the tympanic membrane. The remaining outer part of the first gill-opening is the rudiment of the outer ear-canal. From the inner part originates the tympanic cavity, and further inward, the Eustachian tube. In connection with these, the three bonelets of the ear develop from the first two gill-arches; the hammer and anvil from the first, and the stirrup from the upper end of the second gill-arch.[174]

Finally, as regards the external ear, the ear-shell (*concha auris*), and the outer ear-canal, leading from the shell to the tympanic membrane—these parts develop in the simplest way from the skin-covering which borders the outer orifice of the first gill-opening. At this point the ear-shell rises in the form of a circular fold of skin, in which cartilage and muscles afterwards form (Fig. 238, p. 247). This organ is also limited to Mammals. Among them, it is originally wanting only in the lowest division, in the Beaked Animals, (*Monotrema*). In the others, on the contrary, it appears in very different stages of development and partly also of atrophy. The ear-shell has atrophied in most aquatic

Mammals. Most of these have even lost it entirely; this is so, for example, in the Sea-cows and Whales, and most Seals. On the other hand, in the great majority of Pouched Animals (*Marsupialia*) and Placental Animals (*Placentalia*), the ear-shell is well developed, receives and concentrates the waves of sound, and is provided with a highly-developed muscular apparatus, by means of which it can be turned freely to all sides, and at the same time can be changed in form. Every one must have noticed how strongly and freely our domestic Mammals, Horses, Cows, Dogs, Rabbits, etc., can "prick" their ears, erect them and turn them in different directions. Most Apes yet retain the power of doing this, and our ancient Ape progenitors could also do it. The more recent Ape ancestors, common to Men and to the Anthropoid Apes (Gorilla, Chimpanzee, etc.), discontinued the habit of moving their ears, and hence the motor muscles gradually

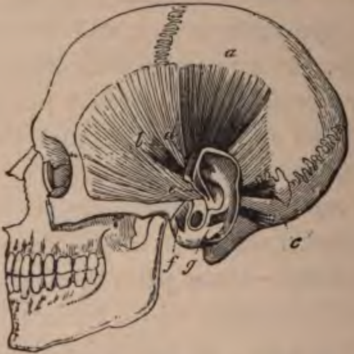


FIG. 250.—Rudimentary ear-muscles on the human skull: *a*, upward muscle (*m. attollens*); *b*, forward muscle (*m. attrahens*); *c*, backward muscle (*m. retrahens*); *d*, larger muscle of the helix (*m. helicis major*); *e*, smaller muscle of the helix (*m. helicis minor*); *f*, muscle of the tragus (*m. tragicus*); *g*, muscle of the antitragus (*m. antitragicus*). (After H. Meyer.)

became rudimentary and useless. We still, however, possess them (Fig. 250). A few individual men can even move their ears forward or backward a little by the use of the forward muscle (*b*) and the backward muscle (*c*); and by long practice these motions can be gradually increased. On the other hand, no man is able to erect the ear-shell by the upward muscle (*a*), or to change its form by the little inner muscles of the ear (*d, e, f, g*). These muscles, which were very useful to our ancestors, have become entirely unimportant to us. This is equally true of Anthropoid Apes.

We also share only with the higher Anthropoid Apes—the Gorilla, Chimpanzee, and Orang—the characteristic form of our human ear-shell, especially the rolled edge, the helix, and the ear-flap. The lower Apes, like all other Mammals, have pointed ears without the helix, and without ear-flaps. Darwin has, however, shown that in some men a short, pointed process, not occurring in most individuals, is perceptible at the upper part of the folded rim of the ear. In some few individuals, this process is very well developed. It can only be explained as the remnant of the original point of the ear which, in consequence of the folding of the edge of the ear, has been bent forward and inward. (Cf. the similarly folded ear in the embryo of the Pig and Cow, Plate VII. Fig. *H* III. and *C* III.) On carefully comparing the ear-shells of Man and of the various Apes in this particular, we find that they form a connected series of retrograde steps. In the common catarhine ancestors of the Anthropoids and of Man, this retrogression began with the folding down of the ear-shell. In consequence of this, the ear-edge was formed on which that significant corner appears, the last trace of the free prominent point of the ear in our older Ape ancestors. Thus it is possible even here, with the help of Comparative Anatomy, to trace this human organ from the similar but more highly-developed organ of the lower Mammals, with certainty. At the same time, Comparative Physiology shows us that this organ is of more or less high physiological value to the latter, while in Anthropoids and Man it is a useless rudimentary organ. Men with their ears cut off can hear as well as they did before. The conveyance of sound is not affected by the loss of the ear-shell. This explains the great diversity in the form and size of the ear-shell in different persons; it shares this high degree of variability with other rudimentary organs.[175]

CHAPTER XXII.

DEVELOPMENT OF THE ORGANS OF MOTION.

The Motive Apparatus of Vertebrates.—These are constituted by the Passive and Active Organs of Motion (Skeleton and Muscles).—The Significance of the Internal Skeleton of Vertebrates.—Structure of the Vertebral Column.—Formation and Number of the Vertebræ.—The Ribs and Breast-bone.—Germ-history of the Vertebral Column.—The Notochord.—The Primitive Vertebral Plates.—The Formation of the Metamera.—Cartilaginous and Bony Vertebræ.—Intervertebral Discs.—Head-skeleton (Skull and Gill-arches).—Vertebral Theory of the Skull (Goethe and Oken, Huxley and Gegenbaur).—Primitive Skull, or Primordial Cranium.—Its Formation from Nine or Ten Coalescent Metamera.—The Gill-arches (Ribs of the Head).—Bones of the Two Pairs of Limbs.—Development of the Five-toed Foot, adapted for Walking, from the Many-toed Fin of the Fish.—The Primitive Fin of the Selachians (*Archipterygium* of Gegenbaur).—Transition of the Pinnate into the Semi-pinnate Fin.—Atrophy of the Rays or Toes of the Fins.—Many-fingered and Five-fingered Vertebrates.—Comparison of the Anterior Limbs (Pectoral Fins) and the Posterior Limbs (Ventral Fins).—Shoulder Girdle and Pelvis Girdle.—Germ-history of the Limbs.—Development of the Muscles.

"In forming his estimate of my entire theory, the reader may begin with the details and examine the fundamental facts on which I base my conclusions. But it is equally necessary to connect the detached facts, and estimate their bearing on the whole. He who in the world of organisms sees only disconnected existences, in which some organic similarities appear as accidental coincidences, will remain a stranger to the results of this investigation; not merely because he does not comprehend the conclusions, but principally because the significance of the facts on which they are grounded, escapes him. A fact in itself is no more a scientific result, than a mere collection of facts is a science. That which makes a science of these facts, is their combination by that organizing mental faculty which determines the relations of the facts to each other."—KARL GEGENBAUR (1872).

AMONG those features of the organization which are specially characteristic of the vertebrate tribe as such, the peculiar arrangement of the motive apparatus, or "locomotorium," undoubtedly occupies a principal place. As in all the higher animals, the active organs of motion, the muscles, form the most important part of this apparatus; these are the fleshy bands which, by means of their peculiar contractibility, of their power of contracting and shortening, move the various parts of the body, and thus change the position of the entire body. The arrangement of these muscles is, however, entirely peculiar in Vertebrates, and differs from the arrangement common to all Invertebrates.

In most lower animals, especially in Worms, we find that the muscles form a simple, thin flesh-layer immediately below the outer skin-covering. This "skin-muscle pouch" is most intimately connected with the skin itself, and the same feature occurs in the tribe of the Soft-bodied Animals (*Mollusca*). In the great group of the Articulated Animals (*Arthropoda*), in the Crab, Spider, Centipede, and Insect classes, we also find a similar feature, but with the difference that in these the skin-covering forms a hard coat of mail; an inflexible skin-skeleton, formed of chitine, and often of carbonated chalk. This outer chitinous coat of mail is jointed in a great variety of ways both on the trunk and on the limbs of Articulated Animals, and the muscular system, the contractile fleshy bands of which are attached to the inside of the chitinous tubes, is correspondingly jointed in an extremely varied manner. The case is exactly reversed in Vertebrates. In these alone an internal hard skeleton develops; an inner cartilaginous or bony frame to which the fleshy muscles are externally attached, and in which they find a firm support. This bony frame forms a combined lever-apparatus, a passive apparatus of motion. The hard parts of this, the arms of the lever, or the bones, are moored against each other by the active movable muscular bands, as by hawsers. This admirable locomotive apparatus, and especially its firm central axis, the vertebral column, is quite peculiar to Vertebrates, on account of which the whole group has long been called that of Vertebrates.

This internal skeleton, notwithstanding the similarity of its first rudiment, has, however, developed so variously and characteristically in the different vertebrate classes, and in the higher classes forms so complex an apparatus, that Comparative Anatomy finds one of its richest mines in this feature. This was recognized as long ago as the beginning of the century by the older Natural Science, which at once seized these very welcome materials with peculiar pleasure. That science also, which is now called in the higher and more philosophical sense, "Comparative Anatomy," has reaped its richest harvest from this field. The Comparative Anatomy of the present day has studied the skeleton of Vertebrates more thoroughly, and revealed the laws of its formation more successfully, than has been the case with any other system of organs of the animal body. Here the well-known and oft-quoted passage, in which Goethe summed up the general result of his investigations in Morphology is especially appropriate:

> "All forms have a resemblance; none is the same as another,
> And their chorus complete points to a mystical law." *

Now that, by the Theory of Descent, we have discovered this "mystical law," have solved this "sacred enigma," now that we can explain the similarity of forms by Heredity, and their dissimilarity by Adaptation, we can find no weapon in the whole rich arsenal of Comparative Anatomy which defends the truth of the Theory of Descent more powerfully than the comparison of the internal skeletons of the various Vertebrates. We may, therefore, expect *à priori* that such comparison is of special importance in our History of the Evolution of Man. The inner vertebrate skeleton is one of those organs as to the Phylogeny of which Comparative Anatomy affords us conclusions far more important and deeper than those to be gained from its Ontogeny.[176]

More than any other system of organs, the internal skeleton of Vertebrates, when studied comparatively, clearly and immediately impresses the observer with the *necessity* of the phylogenetic connection between these allied and yet very varied forms. A thoughtful comparison of the bony frame of Man with that of other Mammals, and of these again with that of lower Vertebrates, is alone sufficient to afford conviction of the true tribal relationship of all Vertebrates. All the separate parts of which this bony frame is composed appear in other Mammals, in a great variety of forms indeed, but yet in the same characteristic arrangement and relative position; and if the comparison of the anatomical conditions of the skeleton is carried out below Mammals, we can prove that a direct and uninterrupted connection exists throughout between these various forms which are apparently so utterly unlike, and can finally be traced from a most simple, common, fundamental form. These facts alone must fully convince every adherent of the Theory of Development that all Vertebrates, including Man, must be traced from a single common parent-form, from a Primitive Vertebrate; for the morphological features of the inner skeleton, and of the muscular system which stands in the closest correlative relations to it, are of such a kind that it is quite impossible to conceive a polyphyletic origin, a descent from several different root-forms. It is impossible, on mature reflection, to accept the theory that the vertebral column with its various appendages, or the skeleton of the limbs with their variously differentiated parts, could have originated on several occasions during the course of the earth's history, and that, consequently, the various Vertebrates must be referred in various lines of descent from Invertebrates. Indeed, it is exactly in this point that Comparative Anatomy and Ontogeny irresistibly drive us to the monophyletic conclusion, that the human race is a very recent offshoot of the same great single trunk, from branches of which all other Vertebrates have also sprung.

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* "Alle Gestalten sind ähnlich, doch keine gleichet der andern;
Und so deutet der Chor auf ein geheimes Gesetz."

In order to obtain a view of the outlines of the development of the human skeleton, we must first take a general survey of its arrangement in the developed Man. (Cf. Table XXXIV. and Fig. 251, the human skeleton from the

TABLE XXXIV.

Systematic Survey of the Arrangement of the Human Skeleton.

A. Central Skeleton, or Axial Skeleton. Spine.

A.a. ***Vertebral Bodies and Upper Arches.***

1. Skull (*Cranium*)	1 *a.* Pre-vertebral skull
	2 *b.* Vertebral skull
2. Vertebral column (*Columna vertebralis*)	7 Neck vertebræ
	12 Chest "
	5 Hip "
	5 Vertebræ of the sacrum
	4 " " " tail (*coccyx*)

A.b. *Lower Vertebral Arches.*

1. Products of the gill-arches	*Producta arcuum branchialium*
2. Ribs and breast-bone	***Costæ et sternum***

B. Bones connecting the Extremities.

B.a. ***Bones connecting the Anterior Limbs: Bones of the Shoulder.***

1. Shoulder-blade	*Scapula*
(2. Primitive key-bone	*Procoracoides* †)
(3 Raven bone	*Coracoides* †)
4. Collar-bone, or key-bone	*Clavicula*

B.b. ***Bones connecting the Lower Limbs: Bones of the Pelvis.***

1. Intestinal bone	***Os ilium***
2. Pubic bone	***Os pubis***
3. Hip-bone	***Os ischi***

C. Jointed Skeleton of the Limbs.

C.a. *Skeleton of the Fore Limbs.*

I. FIRST DIVISION: UPPER ARM.	
1. Upper arm bone	*Humerus*
II. SECOND DIVISION: LOWER ARM.	
2. Spoke-bone	*Radius*
3. Ell-bone	*Ulna*
III. THIRD DIVISION: HAND.	
III. *A.* Wrist	*Carpus*
Original parts.	Modified parts.
a. Radical	= *Scaphoideum*
b. Intermedium	= *Lunatum*
c. Ulnar	= *Triquetrum*
[*d.* Central	= *Intermedium* †]
e Carpal I.	= *Trapezium*
f. " II.	= *Trapezoides*
g. " III.	= *Capitatum*
h. " IV. + V.	= *Hamatum*
III. *B.* Palm of the Hand	*Metacarpus* (5)
III. *C.* Five Fingers (14 bones	*Digiti Phalanges*)

C.b. *Skeleton of the Hind Limbs.*

I. FIRST DIVISION: THIGH.	
1. Thigh-bone	*Femur*
II. SECOND DIVISION: LEG.	
2. Shin-bone	*Tibia*
3. Calf-bone	*Fibula*
III. THIRD DIVISION: FOOT.	
III. Ankle	*Tarsus*
Original parts.	Modified parts.
a. Tibial	= *Astragalus*
b. Intermedium	
c. Fibular	= *Calcaneus*
d. Central	= *Naviculare*
e. Tarsal I.	= *Cuneiform* I
f. " II.	= " II.
g. " III.	= " III.
h. " IV. + V.	= *Cuboides*
III. *B.* Sole of the Foot	*Metatarsus* (5)
III. *C.* Five Toes (14 bones	*Digiti Phalanges*)

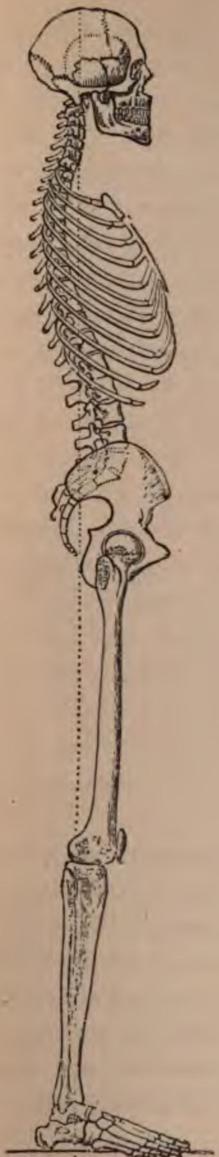


FIG. 251.

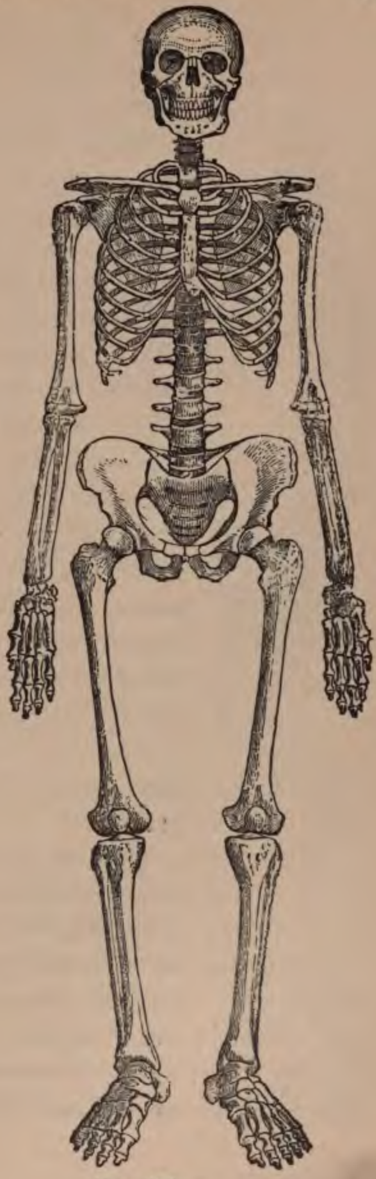


FIG. 252.

right side (without arms); Fig. 252, the entire skeleton from the front.) In Man, as in all other Mammals, the skeleton is primarily distinguishable into the axial skeleton, or spine, and the skeleton of the appendages, or the bony frame of the limbs. The spine consists of the vertebral column and of the skull; the latter being the peculiarly modified anterior part of the former. The ribs are the appendages of the vertebral column; the tongue-bone (*os linguæ*), the lower jaw, and the other products of the gill-arches, are those of the skull. The skeletons of the two pairs of limbs, or extremities, are composed of two different parts: of the bony frame of the actual, prominent extremities, and of the inner girdle skeleton, by which the limbs are attached to the vertebral column. The girdle skeleton of the arms (or fore limbs) is the shoulder girdle; the girdle skeleton of the legs (or the hind limbs) is the pelvic girdle.

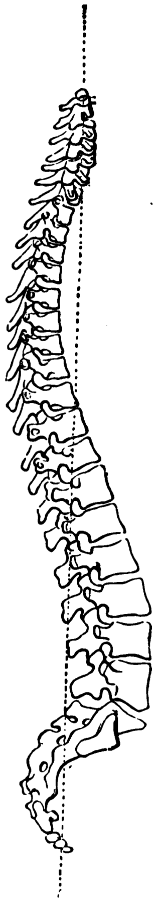
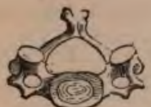
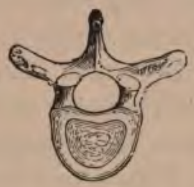


FIG. 253.—Human vertebral column (in an upright position; from the right side). (After H. Meyer.)

The bony vertebral column in human beings (*columna vertebralis*, or *vertebrarium*, Fig. 253) is composed of thirty-three or thirty-four circular pieces of bone, which lie one behind the other (one above the other in the usual upright position of man). These bones (*vertebræ*) are separated from each other by elastic cushions, the intervertebral discs (*ligamenta intervertebralia*), and at the same time, are connected by joints, so that the entire vertebral column forms a firm and solid axis, which is, however, flexible and elastic, capable of moving freely in all directions. In the various regions of the trunk, the vertebræ differ in form and connection, so that the following are distinguished in the human vertebral column, beginning from above: seven neck-vertebræ, twelve breast-vertebræ, five lumbar-vertebræ, five cross-vertebræ, and four to five tail-vertebræ. The uppermost, those directly in contact with the skull, are the neck-vertebræ (Fig. 254), and are distinguished by a hole found in each of the two lateral processes. There are seven neck-vertebræ in Man, as in nearly all other Mammals, whether the neck is long, as in the Camel and the Giraffe, or short, as in the Mole and the Hedgehog. The fact that the number of these neck-vertebræ is always seven,—and there are but few exceptions (explicable by adaptation),—is a strong argument for the common descent of all Mammals; it can only be accounted for as a strict transmission from a common





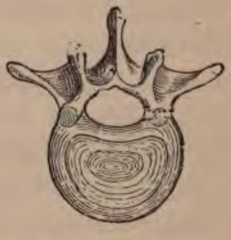


FIG. 254.—Third neck-vertebra of man.
FIG. 255.—Sixth breast-vertebra of man.
FIG. 256.—Second lumbar-vertebra of man.

parent-form, from some Promammal which had seven neck-vertebræ. If each animal species had been a distinct creation, it would have been far more to the purpose to have furnished the long-necked Mammalia with a larger, and the short-necked with a smaller number of neck-vertebræ. The neck-vertebræ are immediately followed by those of the breast or thorax, which, in Man and most other Mammals, number twelve or thirteen (usually twelve). Attached to the sides of each breast-vertebra (Fig. 255) is a pair of ribs—long curved processes of bone lying in and supporting the wall of the thorax. The twelve pairs of ribs, with the connecting intercostal muscles and the breast-bone (*sternum*) constitute the breast-body (*thorax*, Fig. 252, p. 279). In this elastic and yet firm thorax lie the double lung, and between the two halves of this, the heart. The chest-vertebræ are followed by a short but massive section of the vertebral column, formed by five large vertebræ. These are the lumbar-vertebræ (Fig. 256), which bear no ribs and have no perforations in their lateral processes. Next comes the cross-bone (*sacrum*), which is inserted between the two halves of the pelvic girdle. This cross-bone consists of five fixed and amalgamated cross-vertebræ. Last comes a small rudimentary tail-vertebral column, the rump-bone (*coccyx*). This bone consists of a varying number (usually four, more rarely three or five) of small aborted vertebræ; it is a useless rudimentary organ, retaining no physiological significance either in Man or in the Tail-less Apes or Anthropoids. (Cf. Figs. 204–208.) Morphologically it is, however, very interesting, as affording incontrovertible evidence of the descent of Man and of Anthropoids from Long-tailed Apes. For this assumption affords the only possible explanation of this rudimentary tail. In the human embryo, indeed, during the earlier stages of germ-history, the tail projects considerably. (Cf. Plate VII. Fig. *M* II., and Figs. 123, *s*, 124, *s*, vol. i. p. 370.) It afterwards becomes adherent, and is no longer externally visible. Yet traces of the aborted tail-vertebræ, as well as of the rudimentary muscles, which formerly moved them, persist throughout life. According to the earlier anatomists the tail in the female human being has one vertebra more than that of the male (four in the latter, five in the former).[177]

Number of Vertebræ in various Catarhini.		*Neck Vertebræ.*	*Chest or thoracic Vertebræ.*	*Lumbar Vertebræ.*	*Cross or sacral Vertebræ*	*Tail Vertebræ.*	*Total.*
Tail-less	Man (Fig. 208)	7	12	5	5	4	33
	Orang (Fig. 205)	7	12	5	4	5	33
	Gibbon (Fig. 204)	7	13	5	4	3	32
	Gorilla (Fig. 207)	7	13	4	4	5	33
	Chimpanzee (Fig. 203)	7	14	4	4	5	34
Tailed	Mandril (*Mormon choras*)	7	13	6	3	5	34
	Drill (*Mormon leucophæus*) ...	7	12	7	3	8	37
	Rhesus (*Inuus rhesus*)	7	12	7	2	18	46
	Sphinx (*Papio sphinx*)	7	13	6	3	24	53
	Simpai (*Semnopithecus melus*)	7	12	7	3	31	60

The number of vertebræ in the human vertebral column is usually thirty-three in all; but it is an interesting fact that this number frequently varies, one or another vertebra failing, or a new, supernumerary vertebra inserting itself. Not unfrequently, also, a rib, capable of free motion, forms on the last neck-vertebra or on the first lumbar-vertebra, so that thus there are thirteen breast, and six neck, or four lumbar vertebræ. In this way contiguous vertebræ in the different sections of the vertebral column may replace each other. On the other hand, the above comparison of the number of vertebræ in different tail-less and tailed Catarhines shows considerable fluctuations in these numbers even in this one family.[178]

To understand the history of the development of the human vertebral column, we must now study the form and combination of the vertebræ in somewhat greater detail. The main outline of each vertebra is that of a signet ring (Figs. 254–256). The thicker part, which faces the ventral side, is called the body of the vertebra, and it forms a short disc of bone; the thinner forms a semi-circular arch—the vertebral arch, which is turned toward the dorsal side of the body. The arches of all the consecutive vertebræ are so connected by thin ligaments (*ligamenta intercruralia*) that the space enclosed by them all in common forms a long canal. In this spinal, vertebral canal lies, as we have seen, the hind portion of the central nervous system, the spinal marrow. The front part of this, the brain, is enclosed in the skull-cavity, and hence the skull itself is merely the anterior section of the vertebral column, modified in a peculiar way. The base or ventral side of the bladder-shaped brain-capsule was originally formed by a number of coalescent vertebral bodies, the amalgamated upper vertebral arches of which formed the arched or ventral side of the skull.

While the firm, massive vertebral bodies constitute the true central axis of the skeleton, the dorsal arches serve to enclose and protect the central marrow. Analogous arches also develop on the ventral side as a protection for the thoracic and abdominal viscera. These inferior or ventral vertebral arches, proceeding from the ventral side of the vertebral bodies, form a canal in many low Vertebrates in which are enclosed the large blood-vessels on the under surface of the vertebral column—the aorta and the tail vein. In higher Vertebrates most of these inferior vertebral arches are lost or become merely rudimentary. But in the breast section of the vertebral column they develop into strong, independent bony arches, the ribs (*costæ*). The ribs are, in fact, merely large vertebral arches which have become independent, and have broken their original connection with the vertebral bodies. The gill arches, of which we have spoken so often, are of similar origin; they are actual head-ribs in the strictest sense—processes which have actually originated from the lower arches of the skull-vertebræ, and which correspond with the ribs. Even the mode of connection of the right and left halves of the arches on the ventral side is the same in both instances. The chest is closed in front by the intervention, between the upper ribs, of the breast-bone (*sternum*)—a single bone originating from two corresponding side-halves. The gill-body is also closed in front by the intervention of a single piece of bone—the *copula lingualis.*

In now turning from this anatomical examination of the constitution of the vertebral column to the question of its development, I may, as regards the first and most important features in the evolution, refer the reader to the explanation already given of the germ-history of the vertebral column (Chap. XII., vol. i. pp. 369–378). In the first place, it is necessary to recollect the important fact that in Man, as in all other Vertebrates, a simple, unarticulated cartilaginous rod at first occupies the place of the articulated vertebral column. This firm but flexible and elastic cartilaginous rod is the well-known notochord (*chorda dorsalis*). In the lowest Vertebrate, the Amphioxus, this persists throughout life in this very simple form, and permanently constitutes the whole internal skeleton (Fig. 151, *i*, vol. i. p. 420; Plate XI. Fig. 15). But even in the Mantle Animals (*Tunicata*), the nearest invertebrate allies of Vertebrata, we find this same notochord; transitorily in the transient larval tail of Ascidia (Plate X. Fig. 5, *ch*); permanently in the Appendicularia (Fig. 162). The Mantle Animals, as well as the Acrania, have undoubtedly inherited the notochord from a common worm-like parent-form, and these primæval worm ancestors are the Chorda Animals (*Chordonia*, p. 91).

Long before any trace of a skull, limbs, etc., appears in the human embryo or in that of any of the higher Vertebrates—in that early stage when the whole body is represented only by the lyre-shaped germ-disc—in the central line of this latter, directly under the primitive groove or medullary furrow, appears the simple chorda dorsalis. (Cf. Figs. 84–87, vol. i. pp. 297, 298, surface view; Figs. 66–70, 89–93, transverse section; also Plates IV., V., *ch.*) As a cylindrical chord it traverses the longitudinal axis of the body, and is equally pointed at both ends. The cells which compose the chord (Fig. 257, *b*) come, in common with all the other cells of the skeleton, from the skin-fibrous layer. They most resemble certain cartilage cells; a special "chordal tissue" is often said to exist; but this must not be regarded as more than a special form of cartilaginous tissue. At an early period the notochord envelopes itself in a structureless sheath (*a*) as clear as glass, which is secreted by its cells.

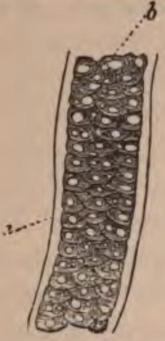
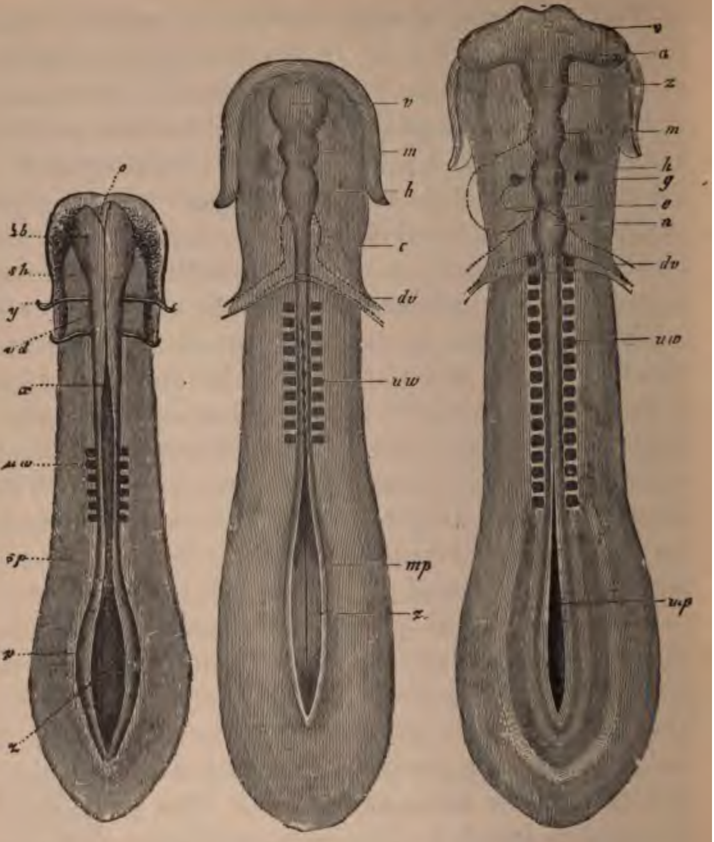


FIG. 257.—Portion of notochord (*chorda dorsalis*) of an embryo sheep: *a*, sheath; *b*, cells. (After Koelliker.)

This perfectly simple, inarticulate, primary axial skeleton is soon replaced by an articulated, secondary axial skeleton, called the "vertebral column." On each side of the notochord the primitive vertebral bands or primitive vertebral plates (vol. i. p. 306, Fig. 92, *uw*) differentiate from the inner portion of the skin-fibrous layer. The inner part of these primitive vertebral bands, which immediately surrounds the notochord, is the skeleton-plate, or skeleton stratum (*i.e.*, the cell-layer forming the skeleton), which furnishes the tissue for the rudiments of the permanent vertebral column and of the skull. In the anterior half of the body the primitive vertebral plate remains a simple, continuous, unbroken layer of tissue, and soon expands into a thin-walled vesicle, which surrounds the brain; this is the primordial skull. In the posterior half, on the contrary, the primitive vertebral plate breaks up into a number of homologous cube-shaped pieces, lying one behind the other, these are the several primitive vertebræ. The number of these is at first very small, but soon increases, as the germ grows in the posterior direction (Figs. 258–260, *uw*). The first and earliest primitive vertebræ are the foremost neck-vertebræ; the posterior neck-vertebræ then originate; then the anterior breast-vertebræ, etc. The lowest of the tail-vertebræ arise last. This successive ontogenetic growth of the vertebral column in a direction from front to rear may be explained phylogenetically by regarding the many-membered vertebrate body as a secondary product, which has originated from an originally inarticulate parent-form by progressive metameric development, or articulation. Just as the many-membered Worms (Earth-worm, Leech) and the closely allied Arthropods (Crabs, Insects) originally



FIGS. 258–260.—Lyre-shaped germ-shield of a Chick, in three consecutive stages of development; seen from the dorsal side; enlarged about twenty times. Fig. 258, with six pairs of primitive vertebræ. The brain is a simple bladder (*hb*). The spinal furrow from *x* remains wide open; behind, at *z*, it is much enlarged. *mp*, Marrow-plates; *sp*, side-plates; *y*, limit between the pharynx cavity (*sh*) and the head-intestine (*vd*). Fig. 259, with ten pairs of primitive vertebræ. The brain has separated into three bladders: *v*, fore-brain; *m*, mid-brain; *h*, hind-brain; *c*, heart; *dv*, yelk-veins. The spinal furrow is still wide open (*z*). *mp*, Marrow-plates. Fig. 260, with sixteen pairs of primitive vertebræ. The brain has separated

into five bladders: *v*, fore-brain; *z*, twixt-brain; *m*, mid-brain; *h*, hind-brain; *n*, after-brain; *a*, eye-vesicles; *g*, ear-vesicles; *c*, heart; *dv*, yelk-veins; *mp*, marrow-plate; *uw*, primitive vertebra.

developed from an inarticulate worm-form by terminal budding, so the many-membered vertebrate body has originated from an inarticulate parent-form. The nearest extant allies of this parent-form are the Appendicularia (Fig. 162) and the Ascidian (Plate XI. Fig. 14).

As has been repeatedly pointed out, this primitive vertebral, or metameric structure has a very important bearing on the higher morphological and physiological development of Vertebrates. (Cf. vol. i. p. 346.) For the articulation is by no means confined to the vertebral column, but equally affects the muscular, nervous, vascular, and other systems. As is shown by the Amphioxus, the metameric structure appeared much earlier in the muscular than in the skeleton system. Each so-called primitive vertebra is in fact far more than the mere rudiment of a future vertebra. In each primitive vertebra exists the rudiment of a segment of the dorsal muscles, of a pair of spinal nerve-roots, etc. Only the inner portion—that which lies directly next to the notochord and the medullary tube—is employed, as the skeleton-plate, in the formation of actual vertebræ. We have already seen how these true vertebræ develop from the skeleton-plate of the primitive vertebræ or metamera. The right and left lateral halves of each primitive vertebra, originally separate, unite. The ventral edges, meeting below the medullary tube, surround the chord and thus form the rudiments of the vertebral bodies; the dorsal edges, meeting above the medullary tube, form the first rudiments of the vertebral arches. (Cf. Figs. 95–98, and Plate IV. Figs. 3–8.)

In all Skulled Animals (*Craniota*), most of the soft, undifferentiated cells which originally constitute the skeleton-plate, afterwards change into cartilage cells, which secrete a firm, elastic "intercellular substance," and thus produce cartilaginous tissue. Like most other parts of the skeleton, the rudimentary vertebræ soon pass into a cartilaginous condition, and, in the higher Vertebrates, the cartilaginous tissue is afterwards replaced by the rigid bony tissue with its peculiar radiate bone-cells (Fig. 5, vol. i. p. 126). The original axis of the vertebral column, the notochord, is more or less compressed by the cartilaginous tissue which grows vigorously round it. In lower Vertebrates (*i.e.*, in Primitive Fishes) a more or less considerable portion of the notochord remains within the vertebral bodies. In Mammals, on the contrary, it disappears almost entirely. In the human embryo, even at the end of the second month, the notochord is seen only as a thin thread which passes through the axis of the thick cartilaginous vertebral column (Fig. 261, *ch*). In the cartilaginous vertebral bodies themselves, which afterwards ossify, the thin remnant of the notochord (Fig. 262, *ch*) soon disappears entirely. A remnant remains, however, throughout life in the elastic "intervertebral discs" which develop, from the skeleton plate, between each pair of vertebral bodies (Fig. 261, *li*). In a new-born child, a large, pear-shaped cavity, filled with a gelatinous cell-mass, is visible in each intervertebral disc

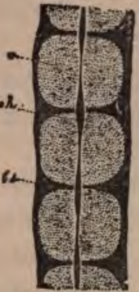
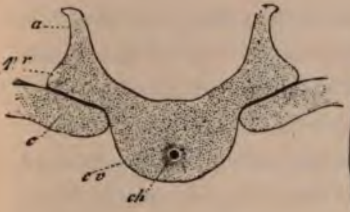


FIG. 261.—Three breast-vertebræ of a human embryo of eight weeks, in lateral longitudinal section: *v*, cartilaginous vertebral bodies; *li*, intervertebral discs; *ch*, notochord. (After Koelliker.)

(Fig. 263, *a*). This "gelatinous nucleus" of the elastic vertebral disc becomes less sharply defined, but persists throughout life in all Mammals, while in Birds and Reptiles, even the last remnant of the notochord vanishes.



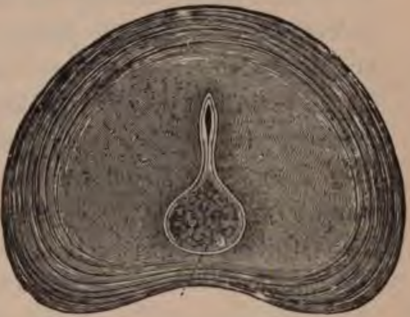


FIG. 262.—A breast-vertebra of the same embryo in lateral cross-section: *cv*, cartilaginous vertebral bodies; *ch*, notochord; *pr*, square process; *a*, vertebral arch (upper); *c*, upper end of rib (lower arch). (After Koelliker.)

FIG. 263.—Intervertebral disc of new-born child in cross-section: *a*, remnant of the notochord. (After Koelliker.)

When the cartilaginous vertebræ afterwards ossify, the first deposit of bone-substance (the first "bone-nucleus") in the vertebral bodies is formed immediately round the remnant of the notochord, and soon completely displaces the latter. A special bone kernel or nucleus is then formed in each half of the cartilaginous vertebral arch. It is not till after birth that the ossification progresses so far that the three bone-nuclei approach each other. The two bony halves of the arch unite during the first year, but it is not till much later, till between the eighth and the twelfth year, that they unite with the bony vertebral body.

The bony skull (*cranium*), which must be regarded as the foremost, peculiarly modified section of the vertebral column, develops in an exactly similar manner. Just as, in the spinal column, the vertebral canal envelopes and protects the dorsal marrow, so the skull forms a bony covering round the brain; and, as the brain is merely the anterior, peculiarly differentiated portion of the dorsal marrow, we might conclude on *à priori* grounds, that the bony envelope of the brain is a peculiar modification of that of the dorsal marrow. It is true, that if the developed human skull (Fig. 264) is considered by itself, it is impossible to understand how it can be merely the modified anterior portion of the vertebral column. It is a complex, capacious bony structure, consisting of no less than twenty bones, differing widely in form and size. Seven of these skull-bones constitute the spacious case which encloses the brain, and in which we distinguish the strong, massive floor of the skull (*basis cranii*) below, and the boldly arched roof of the skull (*fornix cranii*) above. The other thirteen bones form the "facial skull," which especially provides the bony envelopes of the higher sense-organs, and at the same time as the jaw-skeleton, encircles the entrance to the intestinal canal. The lower jaw (usually regarded as the twenty-first skull-bone) is jointed to the skull-floor, and behind this, embedded in the roots of the tongue, we find the tongue-bone, which, like the lower jaw, has originated from the gill-arches, together with a portion of the lower arch, which originally developed as "skull-ribs" from the ventral side of the skull-floor.

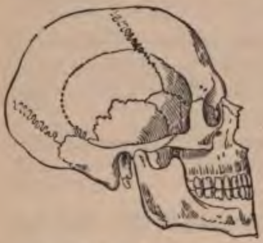


FIG. 264.—Human skull, from the right side.

Although, therefore, the developed skull of the higher Vertebrates, in its peculiar form, its very considerable size, and its complex structure, seems to have nothing in common with ordinary vertebræ, yet the old comparative anatomists at the close of the eighteenth century correctly believed that the skull is originally merely a series of modified vertebræ. In 1790, Goethe "picked up out of the sand of the Jews' burying-ground among the downs near Venice, a dismembered skull of a sheep; he at once perceived that the face bones (like the three vertebræ of the back of the skull) are also derivable from vertebræ." And, in 1806, Oken (without knowing of Goethe's discovery), at Ilsenstein, on the way to the Brocken, "found a beautifully bleached skull of a hind; the thought flashed through him, It is a vertebral column!"[179]

For the last seventy years, this celebrated "Vertebral Theory of the Skull" has interested the most prominent zoologists; the most important representatives of Comparative Anatomy have exercised their ingenuity in attempting to solve this philosophical skull-problem; and the question has engaged attention in yet wider circles. It was not till 1872 that the solution was found, after seven years of labour, by the comparative anatomist, who, both in the wealth of his real empirical knowledge and in the profundity of his philosophic speculations, surpasses all other students of this science. Karl Gegenbaur, in his classic "Researches in the Comparative Anatomy of Vertebrates" (third part), showed that the skull skeleton of the Selachii is the only record which affords definite proof of the vertebral theory of the skull. Earlier comparative anatomists erred in starting from the developed mammalian skull, and in comparing the several component bones with the separate parts of vertebræ; they supposed that in this way they could prove that the developed mammalian skull consists of from three to six original vertebræ. The hindmost of these skull-vertebræ was, according to them, the occipital bone. A second and a third vertebra were represented by the sphenoid bone, with the parietal bones, and by the frontal bone, etc. The elements of anterior skull vertebræ were even supposed to exist in the face bones. In opposition to this view, Huxley first called attention to the fact that in the embryo this bony skull originally develops from a simple cartilaginous vesicle, and that in this simple cartilaginous "primitive skull" not the slightest trace of a constitution of vertebrate parts is visible. This is equally true of the skulls of the lowest and most ancient Skulled Animals (*Craniota*), the Cyclostomi and the Selachii. In these the skull retains throughout life the form of a simple cartilaginous capsule—of an inarticulate "primitive or primordial skull." If the older skull-theory, as it was accepted from Goethe and Oken by most comparative anatomists, were correct, then in these lowest Skulled Animals especially, and in the embryos of the higher Skulled Animals, the constitution of the "primitive skull" by a series of "skull-vertebræ" would be very clearly evident.

This simple and obvious consideration, first duly emphasized by Huxley, indeed overturns the famous "Vertebrate Theory of the Skull," as held by the older comparative anatomists. Yet the entirely correct fundamental idea holds good, *i.e.*, the hypothesis that the skull develops from the anterior portion of the spinal column by differentiation and peculiar modification, just as the brain develops from the anterior portion of the dorsal marrow. But the true mode of empirically establishing this philosophic hypothesis was yet to be discovered; and this discovery we owe to Gegenbaur.[180] He was the first to employ the phylogenetic method, which, in this as in all morphological questions, leads most surely and quickly to the result. He showed that the Primitive Fishes (*Selachii*, Figs. 191, 192, p. 113), as the parent-forms of all Amphirhina, yet retain permanently in their skull-structure that form of primordial skull, from which the modified skull of the higher Vertebrates, and therefore that of Man, has developed phylogenetically. He also pointed out that the gill-arches of the Selachii show that their primordial skull was originally formed of a considerable number—at least nine or ten—primitive vertebræ, and that the brain-nerves, which branch from the base of the brain, entirely confirm this. These brain-nerves—with the exception of the first and the second pairs (the olfactory and the optic nerves)—are merely modified spinal nerves, and, in their peripheric distribution, essentially resemble the latter. The Comparative Anatomy of these brain-nerves is one of the strongest arguments for the newer vertebral theory of the skull.

It would lead us too far aside if we were to enter into the particulars of this ingenious theory of Gegenbaur, and I must content myself with referring to the great work already quoted; in it the theory is fully demonstrated by empirical and philosophical arguments. The same author has given a brief abstract in his "Outlines of Comparative Anatomy" (1874), the study of which it is impossible to recommend too highly. In this work Gegenbaur indicates as original "skull-ribs," or "lower arches of skull-vertebræ," in the selachian skull (Fig. 265), the following pairs of arches: I. and II. are two lip cartilages, of which the anterior (*a*) consists only of an upper, and the inferior (*bc*) of an upper and a lower piece; III., the jaw-arch, which also consists of two pieces on each side,—viz., the primitive upper jaw (*os palato-quadratum*, *o*) and the primitive lower jaw (*u*); IV., the tongue arch (II.), and V. to X., six true gill arches, in the stricter sense of that term (III.–VIII.). The anatomical features of these nine or ten skull-ribs, or "lower vertebral arches," and of the brain nerves distributed over them, show that the apparently simple, cartilaginous "primordial skull" of the Primitive Fishes originally develops from an equal number (nine at the least) of primitive vertebræ. The base of the skull is formed by the vertebral bodies; the roof of the skull by the upper vertebral arches. The coalescence and amalgamation of these into a single capsule is, however, so ancient, that

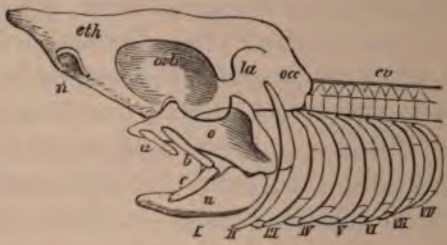


FIG. 265.—Head skeleton of a Primitive Fish: *n*, nose-groove; *eth*, region of the sieve-bone; *orb*, eye-cavity; *la*, wall of ear-labyrinth; *occ*, occipital region of the primitive skull; *cv*, vertebral column; *a*, front; *bc*, hind lip-cartilage; *o*, primitive upper jaw (*palato quadratum*); *u*, primitive lower jaw; II., tongue-arch; III.–VIII., first to sixth gill-arches. (After Gegenbaur.)

their primordial separate condition now appears effaced by the action of the "law of abridged heredity," and is no longer demonstrable in the Ontogeny.

In the human primitive skull (Fig. 266), and in that of all higher Vertebrates, which has been modified, phylogenetically, from the primitive skull of the Selachii, five consecutive divisions are visible at a certain early period of development; these one might be tempted to refer to five original primitive vertebræ; they are, however, merely the result of adaptation to the five primitive brain-bladders, and, like the latter, they rather correspond to a larger number of metamera. The fact that the primitive vertebrate skull is a much modified and profoundly transformed organ, and by no means a primitive structure, is also evident in the circumstance that its rudiment, originally a soft membrane, commonly assumes the cartilaginous state only at its base and on the sides, while it remains membranous at the skull-roof. Here the bones of the later bony skull develop in the soft membranous rudiment as an external bony roof, without a previous intermediate cartilaginous state, as in the base of the skull. Thus a great part of the skull-bones originally developed as roof-bones from the

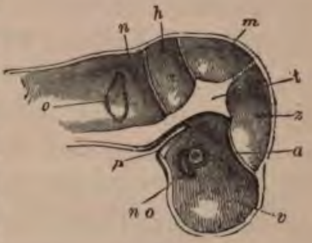


Fig. 266.—Primitive skull of human embryo of four weeks; vertical section, the left half seen from the inside: *v*, *z*, ***m***, ***h***, ***n***, the five grooves in the skull cavity, in which lie the five brain-bladders (fore-brain, twixt-brain, mid-brain, hind-brain, after-brain); *o*, pear-shaped primary ear-vesicle; *a*, eye; *no*, optic nerve; *p*, canal of the hypophysist; *t*, central part of the cranial basis. (After Koelliker.)

leather-skin (*corium*), and only secondarily, come into closer relations with the skull. How, in Man, this most simple and primordial rudiment of the primitive skull develops, ontogenetically, from the head-plates, and how, in the meantime, the anterior extremity of the notochord is enclosed in the base of the skull, has already been explained. (Cf. vol. i. p. 378; Figs. 145 and 146, p. 393.)

The main features in the history of the development of the gill-arches, which must now be regarded as skull-ribs, has been told. Of the four original rudimentary gill-arches of Mammals (Plates I. and VII., Figs. 232–236, p. 243), the first lies between the primitive mouth-opening and the first gill-opening. From the base of this gill-arch the "upper jaw process" develops, and this unites, in the manner already described, with the internal and the external nasal processes on each side, and forms the chief parts of the upper jaw skeleton palate-bones, wing-bones, etc. (Cf. p. 245 and 268.) The rest of the first gill-arch, now distinguished as the "lower-jaw process," forms out of its base two ear bonelets—the hammer (*malleus*) and the anvil (*incus*); the rest of its mass becomes a long strip of cartilage, called, after its discoverer, "Meckel's cartilage." On the external surface of this cartilage originates, as a surface-bone (formed of cellular matter from the leather-plate), the permanent bony lower jaw. From the base of the second gill-arch in Mammalia originate the third ear bonelet, the stirrup (*stapes*), and from the subsequent parts, in order, the stirrup-muscle, the styloid process of the temporal bone, the styloid band, and the small horn of the tongue-bone. Finally, the third gill-arch becomes cartilaginous only at its anterior portion, and here, by the union of its two halves, is formed the body of the tongue-bone (*copula* *hyoidea*) and its great horn on each side. The fourth gill-arch appears in the mammalian embryo only as a transient, rudimentary embryonic organ, and does not develop into special parts. Of the posterior gill-arches (the fifth and sixth pairs), which are permanent in the Primitive Fishes, no trace is visible in the embryo of higher Vertebrates. The latter have long been lost. The four gill-openings in the human embryo are also only interesting as transient rudimentary organs, which soon disappear entirely by concrescence. The first gill-opening (between the first and second gill-arches) alone is of permanent importance; from it develops the drum, or tympanic cavity of the ear, and the Eustachian tube. (Cf. p. 269, and Plate I., with explanation.)

Not only did Gegenbaur, in his model "Researches into the Comparative Anatomy of Vertebrates," first correctly explain the skull and its relation to the vertebral column, but he also first performed the no less weighty and interesting task of showing the phylogenetic derivation of the skeleton of the limbs in all Vertebrates from one primordial form. Few parts of the body in the different Vertebrates are subjected, by adaptation to various circumstances, to such an infinite variety of modifications as the limbs, in point of size, form, and special fitness for certain purposes, and yet we are now able to refer them all to one common hereditary form. Vertebrates are distinguishable as regards the structure of their limbs into three large main groups. The lowest and most ancient Vertebrates, the skull-less and jawless classes, like all their invertebrate ancestors, had no paired limbs; this condition is yet represented in the Amphioxus and in the Cyclostomi (Figs. 189, 190). The second main group consists of the two classes of true Fishes, and of the Dipneusta; in these, two pairs of lateral limbs, in the shape of many-fingered swimming-fins—one pair of pectoral fins (the fore legs) and one pair of abdominal fins (hind legs)—are originally always present (Figs. 191, 192, Plate XII.). Finally, the third main group embraces the four higher vertebrate classes: Amphibia, Reptiles, Birds, and Mammals; in these the same two pairs of legs exist originally, but in the form of five-fingered feet. The digits or fingers are often fewer than five; sometimes, also, the feet are quite aborted. But the original parent-form of the entire group had anteriorly and posteriorly five digits (Pentadactylism, p. 123).

As regards the Phylogeny of the limbs, from their Comparative Anatomy it appears, therefore, that the extremities originated in the Fishes, in the Primitive Fishes (*Selachii*), and were transmitted from these to all higher Vertebrates (all the *Amphirhina*), first in the form of many-fingered fins, and afterwards as five-fingered feet (Figs. 267–272). The anterior extremity—the pectoral fin (or the fore leg)—is originally shaped precisely like the posterior extremity—the ventral fin (or the hind leg). In the one, as in the other, the true limb, externally prominent, is distinguishable from the internal, concealed girdle, by which the limb is attached to the spinal column—the shoulder-girdle above, the pelvic girdle below.

The genuine primitive form of the paired limbs, as it existed in the most ancient of the Primitive Fishes during the Silurian Period, occurs to this day in perfect preservation in the ancient Ceratodus, and very curious Mud-fish of Australia (p. 119, Plate XII.). In this, both the pectoral and the ventral fin is a flat, oval paddle, in which we find a feathered or biserial cartilaginous skeleton (Fig. 267). This skeleton consists firstly of a strong, articulated fin-rod or "stem" (Fig. 267, *A B*), which extends from the base to the tip of the fin, and secondly, of a double row of thin, feathered rays (*rr*), which are attached to both sides of the central rod, like the pinnæ of a pinnate leaf. This primitive fin, first recognized by Gegenbaur, and by him called the *Archipterygium*, is attached to the spinal column by means of a simple girdle in the shape of a cartilaginous arch.[181]

In some Sharks and Rays, especially when very young, this same primitive fin also occurs in a more or less modified form. But in most Primitive Fishes the fin is already essentially modified, in that the rays on one side of the stem are partly or altogether lost, and are retained only on the other side (Fig. 268). Hence arises the half-feathered, or uniserial fish-fin, inherited by the other fishes from the Selachii (Fig. 269).

Gegenbaur first showed how the five-fingered leg of Amphibia is developed from this uniserial fin (Fig. 270) and is inherited by three classes of Amniota. In those Dipneusta which were the ancestors of the Amphibia, the fin rays on the other side of the stem also were gradually degraded in development, and were in a great measure lost (the light-coloured cartilages in Fig. 269). Only the four lowest rays (shaded in Fig. 269) were retained; and these are the four outer digits of the foot (second to fifth digits). The first, or great digit (toe), on the contrary, originated from the lower part of the fin-rod. From the middle and upper parts of this fin-rod developed the long main stem of the limbs

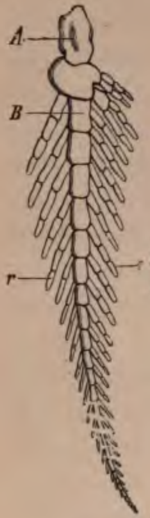


FIG. 267.

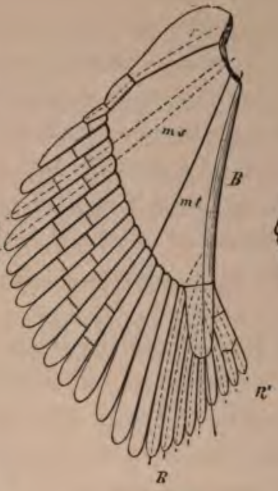


FIG. 268.

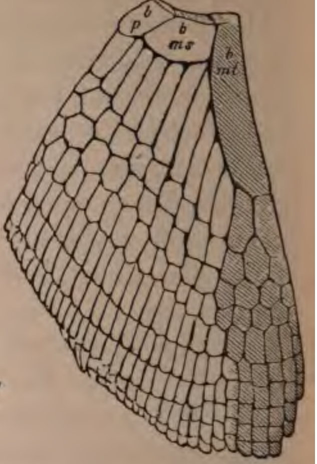


FIG. 269.

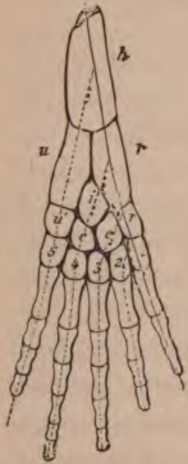


FIG. 270.

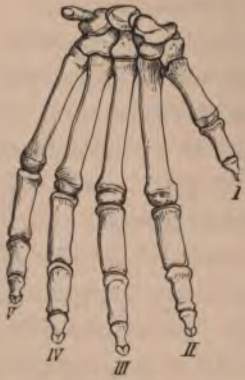


FIG. 271.

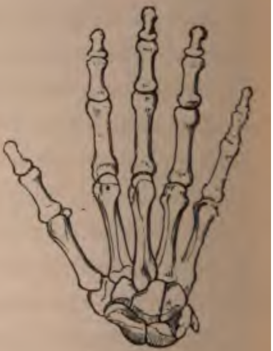


FIG. 272.

FIG. 267.—Bones of pectoral fins of Ceratodus (Archipterygium, or bilateral pinnate skeleton): *A B*, series of cartilaginous pieces forming the ventral stem of the fin; *rr*, rays of the fin. (After Günther.)

FIG. 268.—Bones of pectoral fin of an earlier Primitive Fish (Acanthias). Most of the rays of the medial edge of the fin (*B*) have disappeared; only a few (*R'*) remain. *R R*, rays of the lateral edge of fin; *mt*, Metapterygium; *ms*, Mezopterygium; *p*, Propterygium. (After Gegenbaur.)

FIG. 269.—Bones of pectoral fin of a more recent Primitive Fish, or Selachian. The rays of the medial edge of the fin have entirely disappeared. The shaded part on the right is that portion which develops into the five-fingered hand of higher Vertebrates (*b*, the three basal pieces of the fin; *mt*, Metapterygium; rudiment of the humerus; *ms*, Mezopterygium; *p*, Propterygium). (After Gegenbaur.)

FIG. 270.—Bones of the fore-limb of an Amphibian: *h*, upper arm (*humerus*); *r*, *u*, lower arm (*r*, *radius*; *u*, *ulna*); *r*, *c*, *i*, *c*, *ú*, root-bones of the hand, first row (*r*, radial; *i*, intermediate; *c*, central; *ú*, ulnary); 1, 2, 3, 4, 5, root-bones of the hand, second row. (After Gegenbaur.)

FIG. 271.—Bones of hand of Gorilla. (After Huxley.)

FIG. 272.—Bones of human hand, seen from the back. (After H. Meyer.)

which is so prominent in the higher Vertebrata as the upper arm (or leg) (Fig. 270, *r* and *u*) and the lower arm (or leg, *h*).

The many-fingered fish-fins thus gave rise, by a process of gradual reversion and differentiation, to the five-fingered amphibian foot, which occurs first in the Sozobranchia, and which, from them, has been transmitted on the one hand to Reptiles, and to Mammals, up to Man, on the other (Fig. 272). Simultaneously with the reduction of the number of the fin-rays to four, a further differentiation affected the fin-stem or rod; it became transversely divided into the upper and lower arms (or legs), and a modification took place in the girdle, which in the higher Mammals originally consists, both anteriorly and posteriorly, of three bones. The simple arch of the original shoulder-girdle separates, on each side into an upper (dorsal) piece—the shoulder-blade (*scapula*) and a lower (ventral) piece; the anterior portion of the latter constitutes the pro-key (or collar) bone (*procoracoideum*) and its posterior part the raven-bone (*coracoideum*). The simple arch of the pelvic girdle breaks up, correspondingly, into an upper (dorsal) piece—the intestinal bone (*os ilium*), and a lower (ventral) piece; the anterior portion of the latter becomes the pubic bone (*os pubis*) and the posterior portion the hip-bone (*os ischii*). Table XXXIV., p. 278, shows the correspondence of these three parts of the pelvic girdle with those of the shoulder-girdle. The latter, however, in the key-bone or collar-bone (*clavicula*), possesses a fourth, wanting in the former. (Cf. Gegenbaur.[182])

As in the girdle, so in the trunk of the limbs there is originally an absolute agreement between the anterior and posterior limbs. The first section of the trunk is supported by a single strong bone—in the anterior limbs, the upper arm (*humerus*); in the posterior, the upper leg (*femur*). The second section, on the other hand, contains two bones—on the anterior extremity the spoke-bone (*radius*, Fig. 270, *r*), and the ell-bone (*ulna*, Fig. 270, *u*); in the posterior the two corresponding bones, the shin-bone (*tibia*) and calf-bone (*fibula*). (Cf. skeletons in Fig. 196 and Figs. 204–208). Moreover, the subsequent small and numerous bones of the wrist (*carpus*) and of the ankle (*tarsus*) correspond; so do the five bones of the middle of the hand (*metacarpus*) and of the middle of the foot (*metatarsus*). Finally, the same is true of the five digits attached to these parts, which in their characteristic structure of a series of bone-pieces correspond in the anterior and posterior limbs. Charles Martins, of Montpellier, an excellent morphologist has shown that, in detail, the anterior and posterior limbs correspond.[183]

As Comparative Anatomy thus shows that the skeleton of the limbs in Man is composed of the same bones, and in the same manner as the skeleton in the four higher vertebrate classes, we may justly infer their common descent from a single parent-form. This parent-form was the most ancient Amphibian possessing five digits both on the fore and on the hind limbs. The outermost part of the limbs has, indeed, been very much modified by adaptation to various conditions of life. The diversities in this point within the mammalian class are enormous. The slender limbs of the swift Deer and the strong, springy legs of the Kangaroo, the climbing feet of the Sloth and the digging paws of the Mole, the fins of the Whale and the wings of the Bat, are all instances. It will, of course, be admitted by all that these organs of locomotion are as diverse as possible in point of size, form, and special function. And yet the internal bony skeleton is substantially the same in them all. In all these different forms of limbs the same characteristic bones are always represented in essentially the same strongly inherited combination; and here we have a weighty confirmation of the theory of descent, such as is hardly afforded by the Comparative Anatomy of any other organ. (Cf. Plate IV. p. 34, vol. ii. of "History of Creation.") True, in the limbs of the different Mammals, the skeleton is subject to various arrests of development and reversions, in addition to those due to special adaptation (Fig. 273). Thus, in the fore foot (or hand) of the Dog the first digit, or thumb, is aborted (Fig. 273 II.). In the Pig (III.) and the Tapir (V.) this digit has entirely disappeared. So, too, in the Ruminants (*e.g.*, the Ox, Fig. IV.) the second and fifth digits are also aborted, and only the third and fourth are well developed. Finally, in the Horse, only one digit, the third, is perfectly developed (Fig. VI., 3). And yet all these diverse fore-feet, as also the hand of the Ape (Fig. 271) and the human hand (Fig. 272), have originated from the same common five-fingered parent-form. This is proved, not only by the rudiments of the aborted digits, but also by the homologous disposition of the wrist-bones (Fig. 273, *a–p*). (*Vide supra*, p. 124.)

The same story is also told by the germ-history of the limbs, which is originally identical, not only in all Mammals, but in all Vertebrates. However different the limbs of the various Skulled Animals (*Craniota*) afterwards appear in their fully developed state, they nevertheless all originate from the same simple rudiment. (Cf. Plates VI. and VII.,

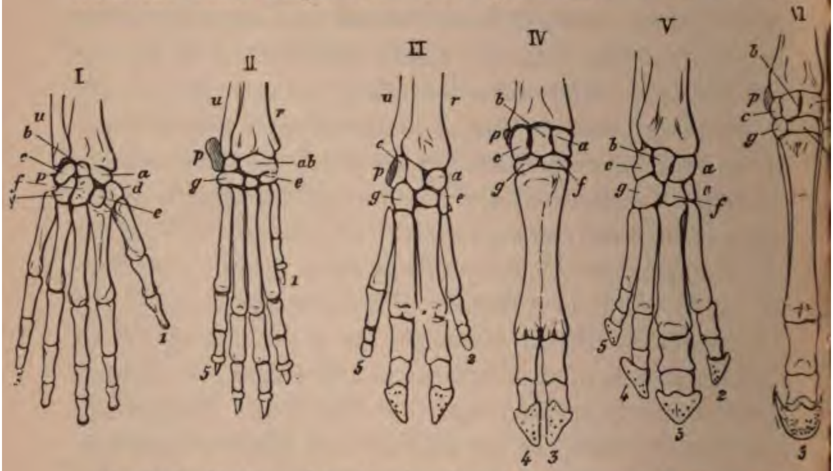


FIG. 273.—Skeleton of hand or fore-foot of six Mammals. I. Man; II. Dog; III. Pig; IV. Ox; V. Tapir; VI. Horse. *r*, Radius; *u*, ulna; *a*, scaphoid; *b*, semi-lunar; *c*, triquetrum (cuneiform); *d*, trapezium; *e*, trapezoid; *f*, capitatum (unciform process); *g*, hamatum (unciform bone); *p*, pisiform; 1, thumb; 2, digit; 3, middle finger; 4, ring finger; 5, little finger. (After Gegenbaur.)

vol. i. p. 362; *f*, fore-leg, *b*, hind-leg.) In all, the first rudiment of each limb in the embryo is a simple wart, or small knob, which grows from the side of the body between the dorsal and ventral sides (Figs. 119 and 120, vol. i. pp. 357, 359; 136 and 137, pp. 381, 382). The cells composing these knobs belong to the skin-fibrous layer. The outer surface is coated by the horn-plate, which is rather thicker at the apex of the protuberance (Plate IV. Fig. 5, *x*). The two anterior protuberances appear at a rather earlier period than the two posterior. By differentiation of the cells, these simple rudiments develop immediately, in Fishes and in the Dipneusta, into fins. In the higher vertebrate classes, on the contrary, each of the four protuberances, in the course of its development, assumes the form of a stalked plate, the inner portion of which being narrower and thicker, the outer broader and thinner. The inner portion, or the handle of the plate, then divides into two sections: the upper and lower legs (or arms). Four notches then appear in the free edge of the plate, and these gradually become deeper; these are the divisions between the five digits (Plate VIII. Fig. 1). The latter soon become more prominent. At first, however, all the five digits, both on the fore and on the hind limbs, are joined by a thin connecting web-like membrane; this recalls the original adaptation of the foot as a swimming-fin. The further development of the limbs from this most simple rudiment takes place in the same way in all Vertebrates; that is, by the modification of certain groups of the cells of the skin-fibrous layer into cartilage, of other groups into muscles, yet others into blood-vessels, nerves, etc. Probably the differentiation of all these various tissues occurs actually in the limbs. Like the vertebral column and the skull, the bony parts of the limbs are also formed at first from soft undifferentiated cell-groups of the skin-fibrous layer. These afterwards change into cartilage, and from these the permanent bones originate by a tertiary process.[184]

The development of the muscles, or the active organs of locomotion, is, as yet, of much less interest than that of the skeleton, or the passive instruments of motion. The Comparative Anatomy of these is, indeed, of much higher importance than their Embryology. But as very little attention has, as yet, been paid to the Comparative Anatomy and Ontogeny of the muscular system, we have only very general ideas of its Phylogeny also. The muscular system as a whole has developed in the most intimate reciprocal correlation with the bone system.[185]

TABLE XXXV.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE HUMAN SKELETON.

I. *First Period: Skeleton of the Chordonia* (Fig. 187, p. 90).

The entire skeleton is formed by the notochord.

II. *Second Period: Skeleton of the Acrania* (Fig. 189, p. 91).

A notochord-membrane, the dorsal continuation of which forms a covering round the medullary tube, is formed round the notochord.

III. *Third Period: Skeleton of the Cyclostomi* (Fig. 190, p. 103).

A cartilaginous primordial skull develops round the anterior extremity of the notochord, from the notochord-membrane. An outer cartilaginous gill-skeleton forms round the gills.

IV. *Fourth Period: Skeleton of the older Selachii* (Fig. 268, p. 302).

A primitive vertebral column, with upper and lower arches (the gill-arches and ribs) forms round the notochord. The remnant of the outer gill-skeleton remains with the inner. Two pairs of limbs, with pinnate (biserial) skeletons, appear.

V. *Fifth Period: Skeleton of the more recent Selachii* (Fig. 269, p. 302).

The anterior gill-arches change into lip-cartilage and jaw-arches. The external gill-skeleton is lost. The skeleton of the two pairs of fins becomes uniserial (semi-pinnate).

VI. *Sixth Period: Skeleton of the Dipneusta* (Fig. 2, Plate XII.).

The skull becomes partially ossified; as does the shoulder-girdle.

VII. *Seventh Period: Skeleton of the Amphibia* (Fig. 270, p. 302).

The gill-arches are modified into parts of the tongue-bone, and of the jaw-apparatus. On the semi-pinnate skeletons of the fins the rays diminish in number to four, thus giving rise to the five-toed foot. The vertebral column ossifies.

VIII. *Eighth Period: Skeleton of the Monotremata* (Fig. 196, p. 148).

The vertebral column, skull, jaws, and limbs, acquire the definite characteristics of Mammals.

IX. *Ninth Period: Skeleton of the Marsupialia* (Fig. 197, p. 152).

The coracoid bone of the shoulder-girdle becomes atrophied, and the remnant of it amalgamates with the shoulder-blade.

X. *Tenth Period: Skeleton of the Semi-apes* (Fig. 199, p. 164).

The pouch-bones, which distinguish Monotremes and Marsupials, disappear.

XI. *Eleventh Period: Skeleton of the Anthropoid Apes* (Figs. 204–208, p. 179).

The skeleton acquires the peculiar development shared by Man exclusively with the Anthropoid Apes.

CHAPTER XXIII.

DEVELOPMENT OF THE INTESTINAL SYSTEM.

The Primitive Intestine of the Gastrula.—Its Homology, or Morphological Identity in all Animals (excepting the Protozoa).—Survey of the Structure of the Developed Intestinal Canal in Man.—The Mouth-cavity.—The Throat (*pharynx*).—The Gullet (*œsophagus*).—The Windpipe (*trachea*) and Lungs.—The Larynx.—The Stomach.—The Small Intestine.—The Liver and Gall-bladder.—The Ventral Salivary Gland (*pancreas*).—The Large Intestine.—The Rectum.—The First Rudiment of the Simple Intestinal Tube.—The Gastrula of the Amphioxus and of Mammals.—Separation of the Germ from the Intestinal Germ Vesicle (Gastrocystis).—The Primitive Intestine (Protogaster) and the After Intestine (Metagaster).—Secondary Formation of the Mouth and Anus from the Outer Skin.—Development of the Intestinal Epithelium from the Intestinal-glandular Layer, and of all other parts of the Intestine from the Intestinal-fibrous Layer.—Simple Intestinal Pouch of the Lower Worms.—Differentiation of the Primitive Intestinal Tube into a Respiratory and a Digestive Intestine.—Gill-intestine and Stomach-Intestine of the Amphioxus and Ascidian.—Origin and Significance of the Gill-openings.—Their Disappearance.—The Gill-arches and the Jaw-skeleton.—Formation of the Teeth.—Development of the Lungs from the Swim-bladder of Fish.—Differentiation of the Stomach.—Development of the Liver and Pancreas.—Differentiation of the Small and Large Intestines.—Formation of the Cloaca.

"Cautious people require us to confine ourselves to gathering materials, and to leave it to posterity to raise a scientific structure from those materials; because only in that way can we escape the ignominy of having the theories we believed in overthrown by the advance of knowledge. The unreasonableness of this demand is apparent enough from the fact that

> Comparative Anatomy, like every other science, is endless; and therefore the endlessness of the accumulation of materials would never allow men, if they complied with this demand, to reap any harvest from this field. But, farther than this, history teaches us clearly, that no age in which scientific inquiry has been active, has been able so to deny itself, as, setting the goal of its researches in the future, to refrain from drawing conclusions for itself from its larger or smaller treasury of observations, and from trying to fill the gaps with hypotheses. It would, indeed, be a hopeless proceeding, if, in order to avoid losing any part of our possessions, we should refuse to acquire any possessions whatever."—KARL ERNST BAER (1819).

AMONG the vegetative organs of the human body, to the development of which we now turn our attention, the intestinal canal is the most important. For the intestinal tube is the oldest of all the organs of the animal body, and carries us back to the earliest time of organological differentiation, to the first period of the Laurentian Epoch. As we have already seen, the result of the first division of labour in the homogeneous cells of the earliest many-celled animal body must have been the formation of a nutritive intestinal canal. The first duty and the first need of every organism is self-support. This task is accomplished by the two functions of nutrition and of the covering of the body. When, therefore, in the primæval collection of homogeneous cells (*Synamœbium*), of the phylogenetic existence of which we yet have evidence in the ontogenetic developmental form of the mulberry-germ (*Morula*), the several members of the community began to divide the work of life, they were first obliged to engage in two separate tasks. One half modified into nutritive cells, enclosing a digestive cavity, the intestinal canal; the other half, on the contrary, developed into covering cells, forming the outer covering of this intestinal canal, and, at the same time, of the whole body. Thus arose the first two germ-layers: the inner, nutritive, or vegetative layer, and the outer, covering, or animal layer.

If we try to construct for ourselves an animal body of the simplest conceivable form, possessing such a primitive intestinal canal, and the two primary germ-layers forming its wall, the result is necessarily the very remarkable germ-form of the gastrula, which we have shown to exist in wonderful uniformity throughout the whole animal series: in the Sponges, Sea-nettles (*Acalephæ*), Worms, Soft-bodied Animals (*Mollusca*), Articulated Animals (*Arthropoda*), and Vertebrates (Figs. 174–179, p. 65). In all these various animal tribes the gastrula reappears in the same entirely simple form (Fig. 274). Its whole body is really merely the intestinal canal; the simple cavity of the body, the digestive intestinal cavity, is the primitive intestine

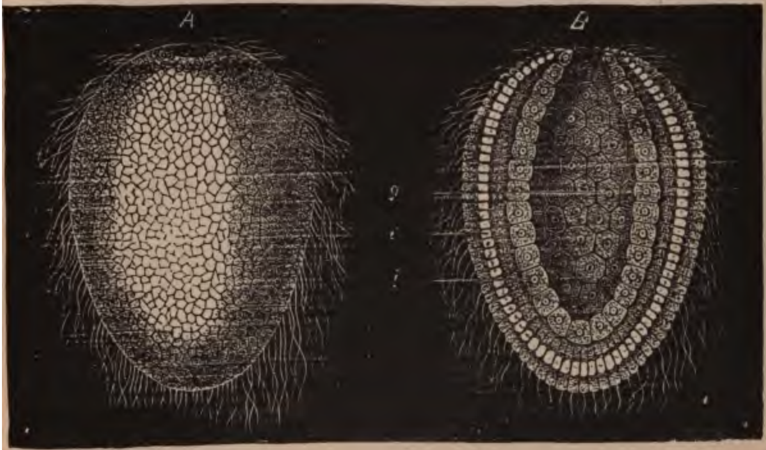


FIG. 274.—Gastrula of a Chalk-sponge (Olynthus): *A*, from outside; *B*, in longitudinal section through the axis; *g*, primitive intestine; *o*, primitive mouth; *i*, intestinal layer, or entoderm; *e*, skin-layer, or exoderm.

(*protogaster, g*); its simple opening, the primitive mouth (*protostoma, o*), is at once mouth and anus; and the two cell-strata which compose its wall, are the two primary germ-layers: the inner, the nutritive, or vegetative germ-layer, is the intestinal layer (*entoderma, i*); and the outer, covering layer, which, by means of its cilia, is also the agent of motion, is the animal layer, or skin-layer (*exoderma, e*). This highly important fact, that the gastrula appears as an early larval condition in the individual development of the most varied animals, and that this gastrula always exhibits the same structure, and that the very differently developed intestinal canals of the most varied animals, arises, ontogenetically, from the same extremely simple gastrula-intestine, this very important fact justifies, in accordance with the fundamental law of Biogeny, two conclusions, which involve important results, and of which one is general and one special. The general conclusion is an inductive one, and may be stated thus: The very variously formed intestinal canal of all the different Intestinal Animals has developed, phylogenetically, from one common and extremely simple primitive intestine, from the intestinal cavity of the Gastræa, that primæval common parent-form which is at the present reproduced, in accordance with the fundamental law of Biogeny, in the gastrula. The second, the special conclusion, which is connected with the former, is deductive, and may be stated thus: The intestinal canal in Man as a whole is homologous with the intestinal canal in all other animals; it has the same original significance, and has developed from the same rudimentary form.[186]

Before proceeding to trace the history of the development of the human intestinal canal in detail, it will be necessary briefly to get a correct idea of the more general conditions of the formation of the intestinal canal in the developed Man. Not until this is known can the development of the several parts be correctly understood. (Cf. Plates IV. and V., vol. i. p. 321.) The intestinal canal in the developed Man is, in all essential points, exactly similar in form to those of all other higher Mammals, and, especially, to that of the Catarhines, the Narrow-nosed Apes of the Old World. The entrance to the intestinal canal is the mouth-opening (Plate V. Fig. 16, *o*). Food and drink pass first through this into the mouth-cavity, in the lower part of which is the tongue. The human mouth-cavity is hedged with thirty-two teeth, attached in two rows to the two jaws, the upper and lower. It has already been stated that the series of teeth is formed in Man exactly as in the Catarhine Apes, but differs from the corresponding part in all other animals (p. 173). Above the mouth-cavity is the double nose-cavity; the two parts of this are separated by the partition-wall of the palate. But, as we have seen, the nasal cavity is not originally separated at all from the mouth-cavity, a common nasal and mouth cavity being primarily formed in the embryo, and this separates at a later period into two separate stories by the hard palate-roof: the upper is the nasal cavity, the lower is the mouth-cavity. The nasal cavity is connected with certain air-filled bony cavities; the jaw-cavities in the upper jaw, the frontal cavities in the frontal bone, and the sphenoid cavities in the sphenoid bone. Numerous glands of various kinds open into the mouth-cavity, particularly many small mucous glands and three pairs of large salivary glands.

The human mouth-cavity is half closed at the back by the vertical curtain which we call the soft palate, and in the centre of the lower part of which is situated the uvula. A glance with the mouth open into a mirror is sufficient to show the form. The uvula is of importance, because it occurs only in Men and in Apes. On both sides of the soft palate are the tonsils (*tonsillæ*). Through the gate-like arched opening situated beneath the soft palate, we pass into the throat-cavity (*pharynx;* Plate V. Fig. 16, *sh*), which lies behind the mouth-cavity. This is only partly visible in the open mouth when reflected in the mirror. Into the throat-cavity a narrow passage opens on each side (the Eustachian tube of the ear), which leads directly into the tympanic cavity of the ear (Fig. 244, *e*, p. 260). The throat-cavity is continued into a long narrow tube, the gullet (*œsophagus, sr*). Through this the masticated and swallowed food passes down into the stomach. The wind-pipe (*trachea, lr*) also opens into the upper part of the throat, and leads thence to the lungs. The opening of this is protected by the epiglottis, over which the food passes. The respiratory organs, the two lungs (Plate IV. Fig. 8, *lu*), are situated, in Man, as in all Mammals, in the right and left sides of the breast-cavity (*thorax*), and midway between them is the heart (Fig. 8, *hr*, *hl*). At the upper end of the wind-pipe (*trachea*), below the epiglottis just spoken of, is a peculiarly differentiated section, the larynx, which is protected by a cartilaginous frame. The larynx is the most important organ of the human voice and speech, and also develops from a part of the intestinal canal. In front of the larynx lies the thyroid gland (*thyreoidea*), which occasionally enlarges to the so-called "goitre."

The gullet (*œsophagus*) passes downward through the thorax, along the vertebral column, behind the lungs and the heart, and enters the ventral cavity, after penetrating the diaphragm. The latter (Fig. 16, *z*) is a membranous, muscular, transverse partition, which in all Mammals (and only in these) completely separates the chest-cavity (*thorax*, $c_{,}$) from the ventral cavity ($c_{,,}$). As has been said, this division does not originally exist; at first a common chest and ventral cavity, the cœloma, or the pleuro-peritoneal cavity, is formed in the embryo. It is only afterwards that the diaphragm forms a muscular, horizontal partition between the chest and the ventral cavities. This partition then completely separates the two cavities, and is penetrated only by separate organs, passing through the chest-cavity into the ventral cavity. One of the most important of these organs is the gullet (*œsophagus*). After this has passed through the diaphragm into the ventral cavity it enlarges into the stomach in which digestion

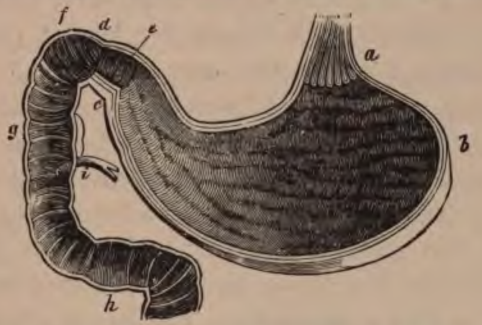


FIG. 275.—Human stomach and gall-intestine in longitudinal section: *a*, cardia (limit of the œsophagus); *b*, fundus (blind sac of the left side); *c*, pylorus fold; *d*, pylorus valve; *e*, pylorus-cavity; *f g h*, gall-intestine; *i*, mouth of the gall-duct and of the pancreas duct. (After H. Meyer.)

especially takes place. The stomach of an adult man (Fig. 275, Plate V. Fig. 16, *mg*) is an oblong sac, placed somewhat obliquely, the left side of which widens into a blind-sac, the base of the stomach or fundus (*b*), while the right side narrows, and passes at the right end, called the pylorus (*e*), into the small intestine. Between these two parts of the intestine is a valve, the pyloric valve (*d*), which only opens when the food-pulp (chyme) passes from the stomach into the small intestine. The stomach itself is the most important digestive organ, and serves especially to dissolve the food. The muscular wall of the stomach is comparatively thick, and, on the outside, has strong muscle-layers, which effect the digestive movements of the stomach;—on the inside, it has a great number of small glands, the gastric glands, which secrete the gastric juice.

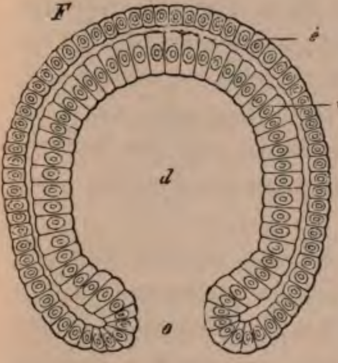
Next to the stomach follows the longest part of the whole intestinal canal, the central, or small intestine (*chylogaster*). Its principal function is to effect the absorption of the fluid mass of digested food, or the food-pulp (chyme), and it is again divided into several sections, the first of which, the one immediately following the stomach, is called the gall-intestine, or "twelve-finger intestine" (*duodenum*, Fig. 275, *f g h*). The gall-intestine forms a short loop curved like a horse-shoe. The largest glands of the intestinal canal open into it: the liver, the most important digestive gland, which furnishes the bile, or gall, and a very large salivary gland, the ventral salivary gland, or pancreas, which secretes the digestive saliva. Both of these glands pour the juices they secrete, the bile and pancreatic juice, into the duodenum (*i*) near each other. In adults the liver is a very large gland, well supplied with blood, lying on the right side immediately below the diaphragm, and separated by the latter from the lungs (Plate V. Fig. 16, *lb*). The pancreas lies somewhat further back and more to the left (Fig. 16, *p*). The small intestine is so long that it has to lie in many folds in order to find room in the limited space of the ventral cavity; these coils are the bowels. They are divided into an upper intestine, called the empty intestine (*jejunum*), and a lower, the crooked intestine (*ilium*). In this latter part lies that part of the small intestine at which, in the embryo, the yelk-sac opens into the intestinal tube. This long, thin intestine then passes into the large intestine, from which it is separated by a peculiar valve. Directly behind this "Bauhinian valve" the first part of the large intestines forms a broad pouch-like expansion, the blind intestine (*cæcum*), the atrophied extremity of which is a well-known rudimentary organ, the vermiform process (*processus vermiformis*). The large intestine (*colon*) consists of three parts; an ascending part on the right, a transverse central part, and a descending part on the left. The latter finally curves like an S, called the "sigmoid flexure," into the last part of the intestinal canal, above the rectum, which opens at the back by the anus (Plate V. Fig. 16, *a*). Both the large intestine and the small intestine are furnished with numerous glands, most of them very small, and which secrete mucous and other juices.

Along the greater part of its length the intestinal canal is attached to the inner dorsal surface of the ventral cavity, or to the lower surface of the vertebral column. It is fastened by means of the thin, membranous plate, called the mesentery, which develops directly under the notochord from the intestinal-fibrous layer, at the point where this curves into the outer lamina of the side-layer, into the skin-fibrous layer (Plate IV. Fig. 5, *g*). The curving-point was distinguished as the middle-plate (Fig. 99, *mp*). The mesentery is, at first, very short (Plate V. Fig. 14, *g*); but it soon lengthens considerably at the central part of the intestinal canal, and takes the form of a thin, transparent, membranous plate, which has to be the more extended the further the folds of the intestine diverge from the place where they are first attached to the vertebral column. The blood-vessels, lymphatic vessels, and nerves which enter the intestinal canal traverse this mesentery.

Although, therefore, the intestinal canal, in the adult human being forms an extremely complex organ, and though it shows in its details so many intricate and delicate structural arrangements,—into which we cannot enter here,—this entire structure has developed, historically, from that simplest form of primitive intestine which was possessed by our gastræad ancestors, and which the extant gastrula now exhibits. We have already shown (in Chapter VIII.) that the peculiar Hood-gastrula (*Amphigastrula*) of Mammals (Fig. 277) may be referred back to the original Bell-gastrula (*Archigastrula*) form, which, among Vertebrates, is now accurately retained solely by the Amphioxus (Fig. 276; Plate X. Fig. 10).

Like the latter, the gastrula of Man and of all Mammals must be regarded as the ontogenetic reproduction of that phylogenetic evolution-form which we call the Gastræa, and in which the whole body of the animal is intestine.

The peculiar form and mode in which the complex human intestinal canal develops from the simple gastrula and which is similar to that in other Mammals, can therefore be only correctly understood when it is considered in the light of Phylogeny. We must, accordingly, distinguish between the original primary intestine ("the primitive intestine, or *protogaster*") of the Skull-less Animals (*Acrania*), and the differentiated or secondary intestine ("after intestine, or *metagaster*") of the Skulled Animals (*Craniota*). The intestine of the Amphioxus (the representative of the *Acrania*) forms no yelk-sac, and develops. palingenetically, from the entire primitive intestine of the gastrula. The intestine of the Skulled Animals, on the other hand, has a modified, kenogenetic form of evolution, and differentiates at a very early period into two different parts: into the permanent secondary intestine, which alone



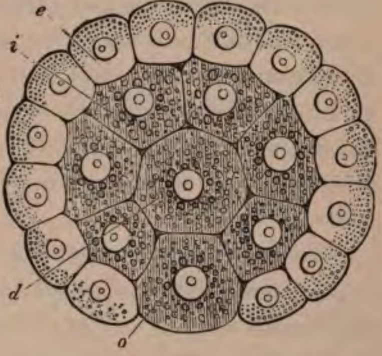


Fig. 276.—Archigastrula of Amphioxus (in longitudinal section): *d*, primitive intestine; *o*, primitive mouth; *i*, intestinal layer; *e*, skin-layer.

Fig. 277.—Amphigastrula of Mammal (in longitudinal section). The primitive intestine (*d*) and primitive mouth (*o*) are filled up by the cells of the intestinal layer (*i*); *e*, skin-layer.

gives rise to the various parts of the differentiated intestinal system, and the transient yelk-sac, which serves only as a storehouse of materials for the building of the embryo. The yelk-sac attains its greatest development in Primitive Fishes (*Selachii*), Bony Fishes (*Teleostei*), Reptiles, and Birds. In Mammals, and especially in Placental Animals, it is atrophied. The peculiar intestinal development of the Cyclostomi, Ganoids, and Amphibia must be regarded as an intermediate form, between the palingenetic intestinal development of the Skull-less animals, and the kenogenetic intestinal development of the Amnion Animals (*Amniota*).[187]

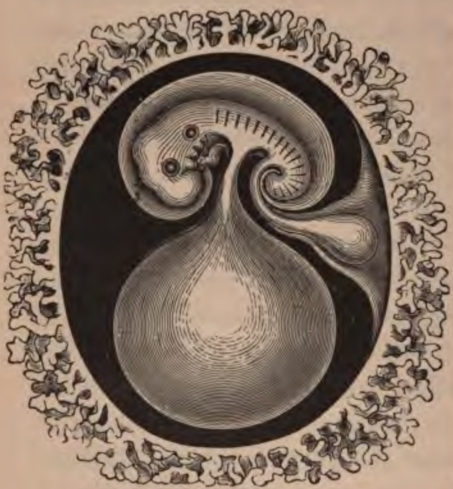
We have already seen in what a peculiar way the development of the intestine takes place ontogenetically in the human embryo and in that of other Mammals. Immediately from the gastrula of these originates a globular intestinal germ-vesicle (*gastrocystis*), filled with fluid (Figs. 72, 73, vol. i. p. 289). In the wall of this is formed the lyre-shaped germ-shield, on the lower side of which, along the middle line, appears a shallow groove, the first rudiment of the future, secondary intestinal tube.

This intestinal groove grows constantly deeper, and its edges curve toward each other, to grow together at last and form a tube (Fig. 100, vol. i. p. 333). The wall of this secondary intestinal tube consists of two membranes of the inner, intestinal-glandular layer, and of the outer, intestinal-fibrous layer. The tube is completely closed at the ends, having only an opening in the centre of the lower wall, by which it is connected with the intestinal germ-vesicle (Plate V. Fig. 14). The latter, in the course of development, becomes continually smaller, as the intestinal canal continues to grow larger and more perfect. While, at first, the intestinal tube appears only as a little appendage on one side of the great intestinal germ-vesicle (Fig. 278), the remnant of the latter afterwards forms only a very inconsiderable appendage of the great intestinal canal. This appendage is the yelk-sac, or navel-vesicle. It entirely loses its importance, and at length disappears, while the intestinal canal is finally closed at the original central opening, where it forms the so-called intestinal navel (Fig. 94, vol. i. p. 312).

It has also been said that this simple cylindrical intestinal tube, in Man as in all Vertebrates, is at first entirely closed at both ends (Plate V. Fig. 14), and that the two permanent openings of the intestinal canal—at the anterior extremity, the mouth, at the posterior, the anus—form only secondarily, and from the outer skin. At the fore end, a shallow mouth-furrow originates in the outer skin, and this grows toward the blind, anterior end of the head intestinal cavity, into which it finally breaks. In the same way a shallow furrow for the anus is formed behind in the skin, and this soon grows deeper, and grows toward the blind posterior end of the pelvic intestinal cavity, with which it finally unites. At both extremities there is, at first, a thin partition between the outer skin-furrow and the blind end of the intestine, and this disappears when the opening is made.[188]

Directly in front of the anus the allantois grows out of the posterior intestine; this is the important embryonic appendage which develops, in Placental Animals, and only in these (thus in Man too) into the placenta (Figs. 278, 279, *l*; Plate V. Fig. 14, *al*). In this more developed form—represented in the diagram (Fig. 94, $_4$, vol. i. p. 312)—the intestinal canal of Man, like that of all other Mammals, now forms a slightly-curved, cylindrical tube, which has an opening at both ends, and from the lower wall of which depend two sacs; the anterior navel-bladder, or yelk-sac, and the posterior allantois, or primitive urinary sac.

Microscopic observation shows that the thin wall of this simple intestinal tube and of its two bladder-like appendages is composed of two distinct cell-strata. The inner, which coats the entire cavity, consists of larger, darker cells,



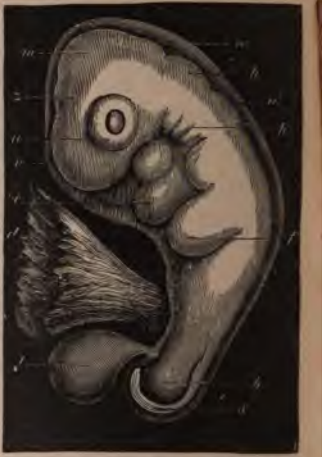


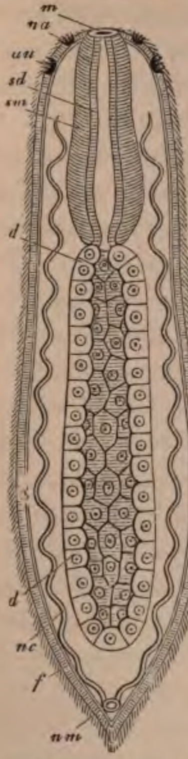
FIG. 278.—Human embryo of the third week, with the amnion and allantois. The great globular yelk-sac is below, the bladder-like allantois on the right; there are as yet no limbs. The germ, with its appendages, is enclosed in the tufted membrane (*chorion*).

FIG. 279.—Human embryo, with amnion and allantois, in the fourth week. (After Krause.) The amnion (*w*) lies pretty close to the body. The greater part of the yelk-sac (*d*) has been torn away. Behind this the allantois appears as a small pear-shaped bladder. Arms (*f*) and legs (*b*) are already commenced: *v*, fore-brain; *z*, twixt-brain; *m*, mid-brain; *h*, hind-brain; *n*, after-brain; *a*, eye; *k*, three gill-arches; *c*, heart; *s*, tail.

and is the intestinal-glandular layer. The outer stratum consists of lighter, smaller cells, and is the intestinal fibrous-layer. The cavities of the mouth and the anus are the only exceptions to this, because they originate from the outer skin. The inner cell-coating of the entire mouth-cavity is therefore furnished, not by the intestinal glandular-layer, but by the skin-sensory layer, and its muscular lower layer, not by the intestinal-fibrous layer, but by the skin-fibrous layer. This is equally true of the wall of the anal cavity (Plate V. Fig. 15).

If the question be asked, what relation these component germ-layers of the primitive intestinal wall bear to the infinitely varied tissues and organs which we afterwards find in the developed intestine, the answer is extremely simple. The relations of these two layers to the formation and differentiation of the tissues of the intestinal canal with all its parts, may be condensed into a single sentence: The intestinal epithelium, that is, the inner, soft cell-stratum which coats the cavities of the intestinal canal and of all its appendages, and which directly accomplishes the nutritive process, develops solely from the intestinal-glandular layer; on the contrary, all other tissues and organs belonging to the intestinal canal and its appendages, proceed from the intestinal-fibrous layer. From this latter, therefore, originates the entire outer covering of the intestinal tube and its appendages; the fibrous connective tissue and the smooth muscles which compose its fleshy skin; the cartilages which support these, for example, the cartilage of the larynx and of the trachea; the numerous blood and lymph vessels which absorb nutrition from the wall of the intestine; in short, everything belonging to the intestine, with the exception of the intestinal epithelium. From the intestinal-fibrous layer originates also the entire mesentery with all the adjacent parts, the heart, the large blood-vessels of the body, etc. (Plate V. Fig. 16).

Let us now turn aside for a moment from this original rudimentary intestine of Mammals, in order to institute a comparison between it and the intestinal canal of those lower Vertebrates and Worms, which we have learned to recognize as the ancestors of Man. In the simplest Gliding-worm, or Turbellaria (*Rhabdocœlum*, Fig. 280), we find a very simple intestinal form. As in the gastrula, the intestine in these Worms is a simple pouch with a single opening, which latter acts both as mouth and anus (*m*). The intestinal pouch has, however, differentiated into two sections, an anterior throat-intestine (*sd*) and a posterior stomach-intestine (*d*). This differentiation becomes more important in the Ascidia (Fig. 281) and in the Amphioxus (Fig. 282), which connects the Worms with the Vertebrates. In these two animal forms the intestine is essentially identical; the anterior portion forms the respiratory gill-intestine, the posterior forms the digestive stomach-intestine. In both it develops, palingenetically, directly from the primitive intestine of the gastrula (Plate XI. Figs. 4, 10). But the original mouth-opening of the gastrula, or the primitive mouth, afterwards closes, and in its place is formed the later anus. In the same way, the mouth-opening of the Amphioxus and of the Ascidian is a new formation, as is the mouth-opening of Man, and generally, of all Skulled Animals (*Craniota*). The secondary formation of the mouth of the Lancelet is connected, as may be conjectured with some probability, with the formation of the gill-openings, which appear directly behind it on the intestine. The front portion of the intestine has thus



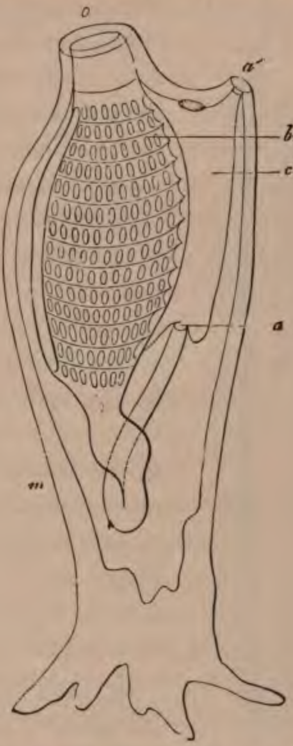


FIG. 280.—A simple Gliding Worm (*Rhabdocœlum*) *m*, mouth; *sd*, throat-epithelium; *sm*, throat muscle-mass; *d*, stomach-intestine; *nc*, renal ducts; *f*, ciliated outer-skin; *nm*, openings of the latter; *au*, eye; *na*, nose-pit.

FIG. 281.—Structure of an Ascidian (seen from the left side, as in Plate XI. Fig. 14). The dorsal side is turned toward the right, the ventral side to the left; the mouth-opening (*o*) is above; at the opposite, tail end, the ascidian has become adherent. The gill-intestine (*br*), perforated by many openings, extends into the stomach-intestine. The terminal intestine opens through the anus (*a*) into the gill-cavity (*cl*), from which the excrement is passed out with the respirated water through the gill-pore, or cloacal opening (*a'*); *m*, mantle. (After Gegenbaur.)

become a respiratory organ. I have already pointed out how characteristic this adaptation is of Vertebrates and Mantle Animals (*Tunicata*, p. 87). The phylogenetic origin of the gill-openings indicates the beginning of a new epoch in the tribal history of Vertebrates.

The most important process we meet with in the further ontogenetic development of the intestinal canal in the human embryo, is the origin of the gill-openings. At the head of the human embryo, the wall of the throat very early unites with the outer wall of the body, and four openings then form on the right and left sides of the neck, behind the mouth, and these lead directly from without into the throat-cavity. These openings are the gill-openings, and the partitions separating them are the gill-arches (Figs. 116–118, vol. i. p. 356; Plates I. and V., Fig. 15, *ks*). These embryonic formations are very interesting; for they show that all the higher Vertebrates when in a very young state,

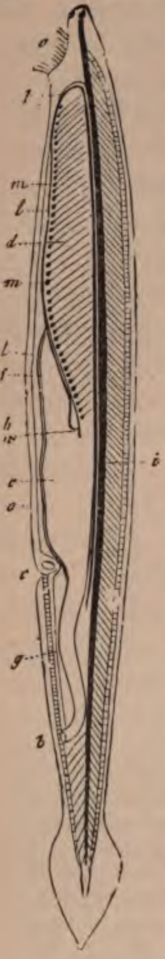


FIG. 282.—Lancelet (*Amphioxus lanceolatus*), double the natural size, seen from the left side (the longitudinal axis is perpendicular, the mouth end above, the tail end below (as in Plate XI. Fig. 15) : *a*, mouth-opening, surrounded by bristles; *b*, anal opening; *c*, gill-pore (*porus branchialis*); *d*, gill-body; *e*, stomach; *f*, liver; *g*, small intestine; *h*, gill-cavity; *i*, notochord, below which is the aorta; *k*, aortal arch; *l*, main stem of the gill-artery; *m*, swellings on the branches of the latter; *n*, hollow vein; *o*, intestinal vein.

reproduce, in accordance with the fundamental principle of Biogeny, the same process which was originally of the greatest importance to the development of the whole vertebrate tribe. This process was the differentiation of the intestinal canal into two sections: an anterior, respiratory part, the gill-intestine, which serves only for breathing, and a posterior, digestive part, the stomach-intestine, which serves only for digestion. As we meet with this very characteristic differentiation of the intestinal tube into two, physiologically, very distinct main sections, not only in the Amphioxus, but also in the Ascidian and the Appendicularia, we can safely conclude that it also existed in our common ancestors, the Chorda Animals (*Chordonia*), especially as even the Acorn Worm (*Balanoglossus*) has it (Fig. 186, p. 86). All other Invertebrate Animals are entirely without this peculiar arrangement.

The number of the gill-openings is still very large in the Amphioxus, as in Ascidians and in the Acorn Worm. In the Skulled Animals it is, on the contrary, very much lessened. Fishes mostly have from four to six pairs of gill-openings. In the embryos of Man and the higher Vertebrates also, only three or four pairs are developed, and these appear at a very early period. The gill-openings are permanent in Fishes, and afford a passage to the water which has been breathed in through the mouth (Figs. 191, 192, p. 113; Plate V. Fig. 13, *ks*). On the other hand, the Amphibians lose them partially, and all the higher Vertebrates entirely. In the latter, only a single vestige of the gill-openings remains, the remnant of the first gill-opening. This changes into a part of the organ of hearing; from it originates the outer ear-canal, the tympanic cavity, and the Eustachian tube.

TABLE XXXVI.

Systematic Survey of the Development of the Human Intestinal System.

N.B.—The parts marked thus † are processes from the intestinal tube.

I. First main section of the Intestinal System: the Respiratory Intestine (Gill Intestine). PNEOGASTER. (*Tractus respiratorius.*)	1. Mouth-cavity (*Cavum oris*)	Mouth-opening	*Rima oris*	Intestinal wall formed by the skin-layer (*Exoderma*)
		Lips	*Labia*	
		Jaws	*Maxillæ*	
		Teeth	*Dentes*	
		Tongue	*Lingua*	
		Tongue bone	*Os hyoides*	
		† Salivary glands	*Glandulæ salivales*	
		Soft palate	*Velum palatinum*	
		Uvula	*Uvula*	
	2. Nose-cavity (*Cavum nasi*)	Nose canal	*Meatus narium*	
		† Jaw cavities	*Sinus maxillares*	
		† Frontal cavities	*Sinus frontales*	
		† Ethmoid cavity	*Sinus ethmoidales*	
	3. Throat-cavity (*Cavum pharyngis*)	Isthmus of the throat	*Isthmus faucium*	Intestinal wall formed by the intestinal layer (*Entoderma*) (excepting the cavity of the Anus, which is formed by the skin-layer).
		Tonsils	*Tonsillæ*	
		Pharynx	*Pharynx*	
		† Eustachian tube	*Tuba Eustachii*	
		† Tympanic cavity	*Cavum tympani*	
		† Brain-appendage	*Hypophysis*	
		† Thyroid gland	*Thyreoidea*	
	4. Lung-cavity (*Cavum pulmonis*)	† Larynx	*Larynx*	
		† Windpipe	*Trachea*	
		† Lungs	*Pulmones*	
II. Second main section of the Intestinal System: Digestive Intestine (Stomach Intestine). PEPTOGASTER. (*Tractus digestivus.*)	5. Anterior Intestine (*Prosogaster*)	Gullet	*Œsophagus*	
		Stomach-opening	*Cardia*	
		Stomach	*Stomachus*	
		Stomach exit	*Pylorus*	
	6. Central Intestine (*Mesogaster*)	Gall-intestine	*Duodenum*	
		† Liver	*Hepar*	
		† Pancreas	*Pancreas*	
		Empty intestine	*Jejunum*	
		(† Yelk-sac, or navel-bladder)	(*Vesicula umbilicalis*)	
		Crooked intestine	*Ileum*	
	7. Posterior Intestine (*Epigaster*)	Large intestine	*Colon*	
		† Blind intestine	*Cæcum*	
		† Vermiform process of the cœcum	*Processus vermiformis*	
		Rectum	*Rectum*	
		Anal opening	*Anus*	
	8. Urinary Intestine (*Urogaster*)	(† Primitive urinary sac	*Allantois*)	
		† Urinary tube	*Urethra*	
		† Urinary bladder	*Urocystis*	

We have already considered this remarkable formation, and will only call attention once more to the interesting fact that the human middle and external ear is the last remnant of the gill-opening of a Fish. The gill-arches, also, which separate the gill-openings, develop into very various parts. In Fishes they remain permanently as gill-arches, carrying the respiratory gill-tufts; so also in the lowest Amphibia; but in the higher Amphibia they undergo various modifications in the course of development, and in all the three higher vertebrate classes, thus also in Man, the tongue-bone (*os hyoides*) and the bonelets of the ear originate from the gill-arches. (Cf. Plates VI. and VII.)

From the first gill-arch, from the centre of the inner surface of which the muscular tongue grows, proceeds the rudimentary jaw-skeleton; the upper and lower jaws which enclose the cavity of the mouth and carry the teeth. The Acrania and Monorhina are entirely destitute of these important parts. They first appear in the genuine Fishes, and have been transmitted by these to the higher Vertebrates. The original formation of the human mouth-skeleton, of the upper and lower jaws, can thus be traced back to the earliest Fishes, from which we have inherited them. The teeth originate from the outer skin-covering which covers the jaws; for, as the formation of the whole mouth-cavity takes place from the outer germ-layer, the teeth must, of course, also have developed originally from the skin-layer. This can be actually proved by close microscopic examination of the most delicate structural features of the teeth. The scales of Fishes, especially of Sharks, are, in this respect, exactly similar to their teeth (Fig. 283). Thus the human teeth, in their earliest origin, are modified fish-scales.[188] On similar grounds we must regard the salivary glands, which open into the mouth-cavity, as really outer-skin (epidermic) glands, which have not developed, like the other intestinal glands, from the intestinal-glandular layer of the intestinal canal, but from the outer skin, from the horn-plate of the outer germ-layer. It is evident that, as the mouth develops in this way, the salivary glands must be placed genetically in the same series with the sweat, sebaceous, and milk glands of the epidermis.

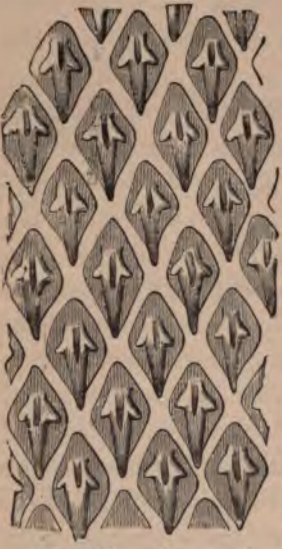
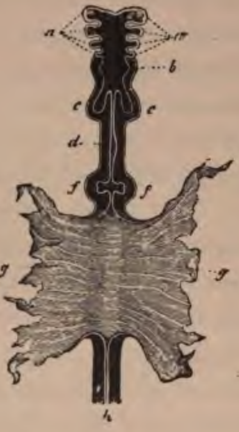


FIG. 283. — Scales of a Shark (*Centrophorus calceus*). On each rhomboid bone-tablet, lying in the leather-skin, rises a small, three-cornered tooth. (After Gegenbaur.)

The human intestinal canal is therefore quite as simple in its original formation as the primitive intestine of the gastrula. It also resembles that of the lowest Worms. It then differentiates into two sections, an anterior gill-intestine, and a posterior stomach-intestine, like the intestinal canal of the Lancelet and the Ascidian. By the development of the jaws and gill-arches it is modified into a true Fish-intestine. Afterwards, however, the gill-intestine, which is a memorial of the Fish-ancestors, as such, is entirely lost. The parts that remain take a wholly different form; but notwithstanding that the anterior section of our intestinal canal thus surrenders entirely its original form of gill-intestine, it yet retains its physiological function as a respiratory intestine; for the extremely interesting and remarkable discovery is now made that even the permanent respiratory organ of the higher Vertebrates, the air-breathing lungs, has also developed from this anterior section of the intestinal canal. Our lungs, together with the wind-pipe (*trachea*) and the larynx, develop from the ventral wall of the anterior intestine. This entire great breathing-apparatus, which occupies the greater part of the chest (*thorax*) in the developed Man, is at first merely a very small and simple vesicle or sac, which grows out from the intestinal canal immediately behind the gills, and soon separates into two lateral halves (Figs., 284, *c*, 285, *c*; Plate V. Figs. 13, 15, 16, *lu*). This vesicle occurs in all Vertebrates except in the two lowest classes, the Acrania and Cyclostomi. In the lower Vertebrates, however, it develops, not into lungs, but into an air-filled bladder of considerable size, occupying a great part of the body-cavity (*cœloma*), and which is of quite a different significance from the lungs. It serves, not for breathing, but as an hydrostatic apparatus: for vertical swimming movements it is the swimming-bladder of Fish; but the lungs of Man and of all other air-breathing Vertebrates develop from the same simple bladder-like appendage of the anterior intestine, which, in Fishes, becomes the swimming-bladder.

Originally this sac also has no respiratory function, but serves only as an hydrostatic apparatus, augmenting or diminishing the specific gravity of the body. Fishes, in which the swimming-bladder is fully developed, are able to compress it, and thus to condense the air contained in it. The air sometimes also escapes from the intestinal canal through an air-passage which connects the swimming-bladder with the throat (*pharynx*), and is expelled through the mouth; in this way the circumference of the swimming-bladder is diminished, and the fish becomes heavier and sinks. When the animal is again about to ascend, the swimming-bladder is distended by remitting the compressing force. This hydrostatic apparatus begins to be transformed into a respiratory organ in the Mud-fishes (*Dipneusta*), the blood-vessels in the wall of the swimming-bladder no longer merely separating air, but also inhaling fresh air, which has come in through the air-passage. This process is fully developed in all Amphibia. The original swimming-bladder here generally becomes a



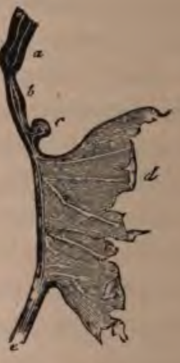


FIG. 284.—Intestine of an embryonic Dog (which is represented in Fig. 137, vol. i. p. 382; after Bischoff), from the ventral side: *a*, gill-arches (four pairs); *b*, rudimentary throat and larynx; *c*, lungs; *d*, stomach; *f*, liver; *g*, walls of the opened yelk-sac, into which the central intestine opens by a wide aperture; *h*, rectum.

FIG. 285.—The same intestine, seen from the right side: *a*, lungs; *b*, stomach; *c*, liver; *d*, yelk-sac; *e*, rectum.

lung, and its air-passage a wind-pipe. The amphibian lung has been transmitted to the three higher vertebrate classes, and even in the lowest Amphibia the lung on either side is as yet a very simple, transparent, thin-walled sac—as, for instance, in our common Water-Newts, or Tritons, and very like the swimming-bladder of Fishes. The Amphibia have, it is true, two lungs, a right and a left; but in many Fishes also (in the ancient Ganoids) the swimming-bladder is double, the organ being divided into a right and a left half. On the other hand, the lung of the Ceratodus is single (p. 119). The earliest rudiment of the lung in the human embryo and in the embryo of all higher Vertebrates is also a simple, single vesicle, which does not separate till afterwards into a pair of halves—the right and the left lung. At a later period, the two vesicles grow considerably, occupy the greater part of the chest cavity, and lie one on each side of the heart; even in Frogs we find that the simple sac, in the course of its development, is transformed into a spongy body of a peculiar, froth-like texture. This lung-tissue develops as a tree-like, branched gland, bearing berry-like appendages. The process by which the lung-sac was attached to the anterior intestine, which was originally very short, lengthens, by simple growth, into a long thin tube; this tube is the wind-pipe (*trachea*); it opens above into the throat (*pharynx*), and below divides into two branches which pass into the two lungs. In the wall of the wind-pipe ring-shaped cartilages develop, which keep the whole distended; at the upper end of this wind-pipe, below its entrance into the throat, the larynx, the organ of voice and speech, develops. The larynx occurs even in Amphibia in very various stages of development, and with the aid of

Comparative Anatomy we can trace the progressive development of this important organ from its very simple rudiment in the lower Amphibia up to the complex and vocal apparatus represented by the larynx of Birds and Mammals.

Though these organs of voice, speech, and air-respiration develop so differently in the various higher Mammals, they yet all arise from the same simple original rudiment—from a vesicle which grows out of the wall of the anterior intestine. We have thus satisfied ourselves of the interesting fact that both the respiratory apparatus of Vertebrates develop from the fore part of the intestinal canal; first, the primary and more primitive water-respiring apparatus, the gill-body, which is altogether lost in the three higher vertebrate classes; and, afterwards, the secondary and more recent air-breathing apparatus, which acts in Fishes only as a swimming-bladder, but as a lung from the Dipneusta upwards.

We must say a few words about an interesting rudimentary organ of the respiratory intestine, the thyroid gland (*thyreoidea*), the large gland situated in front of the larynx, and below the so-called "Adam's apple," and which, especially in the male sex, is often very prominent; it is produced in the embryo by the separation of the lower wall of the throat (*pharynx*). This thyroid gland is of no use whatever to man; it is only æsthetically interesting, because in certain mountainous districts it has a tendency to enlarge, and in that case it forms the "goitre" which hangs from the neck in front. Its dysteleological interest is, however, far higher; for as Wilhelm Müller of Jena has shown, this useless and unsightly organ is the last remnant of the "hypobranchial groove," which we have already considered, and which, in the Ascidia and in the Amphioxus, traverses the middle of the gill-body, and is of great importance in conducting the food into the stomach (vol. i. p. 420; Plate XI. Figs. 14–16, *y*).[189]

The second main section of the intestinal canal, the stomach or digestive intestine, undergoes modifications no less important than those affecting the first main section. On tracing the further development of this digestive section of the intestinal tube, we again find a very complex and composite organ eventually produced from a very simple rudiment. For the sake of rendering the matter more intelligible, we may distinguish the digestive intestine into three parts: the fore intestine (with the gullet and stomach); the middle intestine, the gall-intestine (with the liver and pancreas); the empty intestine (*jejunum*), and crooked intestine (*ileus*); and the hind intestine (large intestine and rectum). Here we again find protuberances or appendages of the originally simple intestinal tube which change into very various structures. We have already discussed two of these appendages—the yelk-sac, which protrudes from the middle of the intestinal tube (Fig. 286, *c*), and the allantois, which grows out of the last portion of the pelvic intestine as a large sac-like protuberance (*u*). The protuberances from the middle of the intestine are the two great glands which open into the duodenum, the liver (*h*) and the ventral salivary gland.

Immediately behind the bladder-like rudiment of the lungs (Fig. 286, *l*) comes that portion of the intestinal tube which forms the most important part of the digestive apparatus, viz., the stomach (Figs. 284, *d*, 285, *b*). This sac-shaped organ, in which the food is especially dissolved and digested, is not so complex in structure in the lower Vertebrates as in the higher. Thus, for instance, in many Fishes, it appears as a very simple spindle-shaped expansion at the

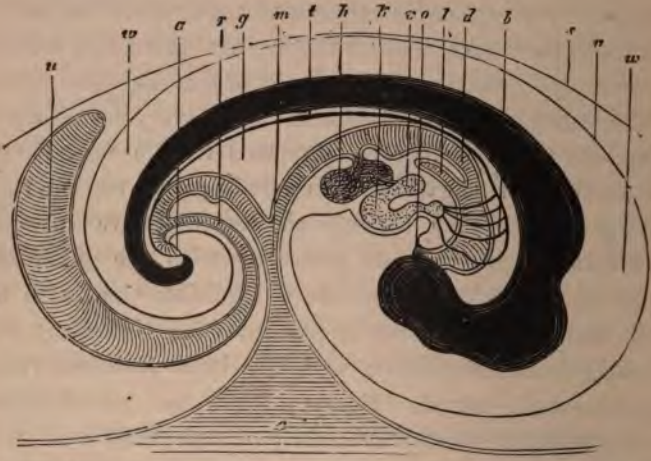


FIG. 286.—Longitudinal section through an embryonic Chick on the fifth day of incubation: *d*, intestine; *o*, mouth; *a*, anus; *l*, lungs; *h*, liver; *q*, mesentery; *v*, auricle of heart; *k*, ventricle of heart; *b*, arterial arches; *t*, aorta; *c*, yelk-sac; *m*, yelk-duct; *u*, allantois; *r*, stalk of allantois; *n*, amnion; *w*, amnion-cavity; *s*, serous membrane. (After Baer.)

beginning of the digestive section of the intestine, which latter passes from front to rear in a straight line under the spinal column in the central plane of the body. In Mammals the rudiment of this organ is as simple as it thus is permanently in Fishes. but at a very early period the various parts of the stomach-sac begin to develop unequally. As the left side of the spindle-shaped pouch grows much more vigorously than the right, and as, at the same time, there occurs a considerable obliquity of its axis, it soon assumes an oblique position. The upper end lies more to the left and the lower end more to the right. The anterior end extends so as to form the long narrow canal of the gullet (*œsophagus*); below the latter, the blind-sac of the stomach (*fundus*) bulges out to the left, and thus the later form of the stomach is gradually developed (Fig. 287, *e*; Fig. 275, p. 317). The axis, which was originally vertical, now inclines from a higher point on the left to a lower on the right, and continually acquires a more transverse direction. In the outer stratum of the stomach-wall, and from the intestinal-fibrous layer, develop the strong muscles which perform the powerful digestive movements. In

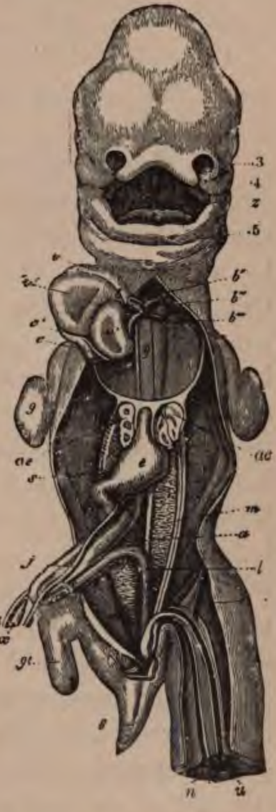


FIG. 287.—Human embryo of five weeks, from the ventral side; opened (enlarged). The breast wall, abdominal wall, and liver, have been removed. 3, external nasal process; 4, upper jaw; 5, lower jaw; *z*, tongue; *v*, right, *v'*, left ventricle of heart; *o'*, left auricle of heart; *b*, origin of aorta; *b' b'' b'''*, 1st, 2nd, 3rd aorta-arches; *c c' c''*, hollow vein; *ae*, lungs (*y*, lung-arteries); *e*, stomach; *m*, primitive kidneys (*j*, left yelk-vein; *s*, pylorus; *a*, right yelk-artery; *n*, navel-artery; *u*, navel-vein); *x*, yelk-duct; *i*, terminal intestine; 8, tail; 9, fore-limb; 9', hind-limb. (After Coste.)

the inner stratum, on the contrary, innumerable minor glands develop from the intestinal-glandular layer. These are the peptic glands, which supply the most important digestive fluid—the gastric juice. At the lower extremity of the pouch of the stomach a valve develops, which, as the pylorus, separates the stomach from the small intestine (Fig. 275, *d*).

The disproportionately long middle intestine, or small intestine, now develops below the stomach. The development of this section is very simple, and is essentially caused by a very rapid and considerable longitudinal growth. Originally this section is very short, straight, and simple; but immediately below the stomach a horseshoe bend, or loop, begins to appear at a very early period in the intestinal canal, simultaneously with the separation of the intestinal tube from the yelk-sac and with the development of the mesentery. (Cf. Plate V. Fig. 14, *g*, and Fig. 136, vol. i. p. 381.) Before the abdominal wall closes, a horseshoe-shaped loop of intestine (Fig. 136, *m*) protrudes from the ventral opening of the embryo, and into the curve of this the yelk-sac or navel-bladder opens (*n*). The thin, delicate membrane which secures this intestinal loop to the ventral side of the vertebral column, and occupies the inside of this horseshoe curve, is the first rudiment of the mesentery (Fig. 286, *g*). The most prominent part of the loop into which the yelk-sac opens (Fig. 287, *x*), and which is afterwards closed by the intestinal navel, represents that part of the small intestine which is afterwards called the crooked intestine (*ileum*). Soon a very considerable growth of the small intestine is observable; and in consequence, this part has to coil itself in many loops. The various parts of the small intestine which we have yet to distinguish differentiate later in a very simple way; these are the gall-intestine (*duodenum*), which is next to the stomach, the long empty intestine (*jejunum*) which succeeds, and the last section of the small intestine, the crooked intestine (*ileum*).

The two large glands which we have already named, the liver and the ventral salivary gland, grow out, as protuberances, from the gall-intestine, or duodenum. The liver first appears in the form of two small sacs, situated right and left just behind the stomach (Figs. 284, *f*, 285, *c*). In many low Vertebrates the two livers remain quite separate for a long time (in the Myxinoides for life), and coalesce only imperfectly. In higher Vertebrates, on the other hand, the two livers coalesce more or less completely at an early period, and constitute one large organ. The intestinal-glandular layer, which lines the hollow, pouch-like rudiment of the liver, sends a number of branched processes into the investing intestinal-fibrous layer; as these solid processes (rows of gland-cells) again branch out, and as their branches coalesce, the peculiar netted structure of the developed liver is produced. The liver-cells, as the secreting organs which form the bile, all originate from the intestinal-glandular layer. The fibrous mass of connective tissue, which joins this great cellular network into a large compact organ, and which invests the whole, comes, on the other hand, from the intestinal-fibrous layer. From the latter originate also the great blood-vessels which traverse the entire liver, and the innumerable netted branches of which are interlaced with the network of the liver-cells. The gall-ducts, which traverse the entire liver, collecting the bile and discharging it into the intestine, originate as intercellular passages along the axis of the solid cell-cords; they all discharge into the two primitive main gall or biliary ducts, which originate from the base of the two original protuberances of the intestine. In Man, and in many other Vertebrates, these two ducts afterwards unite, and form one simple gall-duct, which discharges into the ascending portion of the gall-intestine. The gall bladder originates as a hollow protuberance of the right primitive liver duct. The growth of the liver is at first exceedingly rapid; in the human embryo, even in the second month, it attains such dimensions that during the third month it occupies by far the largest part of the body-cavity (Fig. 288). At first, both halves are equally well developed; afterwards the left half lies considerably behind the right. In consequence of the asymmetrical development and alteration in the position of the stomach and other abdominal viscera, the whole of the liver is eventually forced over on to the right side. Although the growth of the liver is, afterwards, not so excessive, even at the end of gestation, it is comparatively much larger in the embryo than in the adult. In the latter, its weight

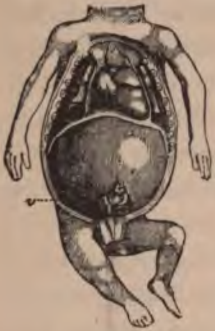


FIG. 288.—Chest and abdominal viscera of a human embryo of twelve weeks, in natural size. (After Koelliker.) The head is omitted; the chest and abdominal walls removed. The greater part of the abdominal cavity is occupied by the liver, from an opening in the centre of which the blind-intestine (*cæcum*, *v*), with the worm appendage, protrudes. Above the diaphragm the heart is visible in the centre, with the small lungs on the right and left.

in proportion to that of the whole body is as 1:36; in the former, as 1:18. The physiological significance of the liver during embryonic life—which is very great—depends especially on the part it plays in the formation of blood, and less on its secretion of bile.

From the gall-intestine, immediately behind the liver, grows another large intestinal gland, the ventral-salivary gland, or pancreas. This organ, which occurs only in Skulled Animals, also develops as a hollow sac-shaped protuberance of the intestinal wall. The intestinal-glandular layer of the latter sends out branching shoots, which afterwards become hollow. The ventral-salivary gland, just like the salivary glands of the mouth, develops into a large and very complex gland shaped like a bunch of grapes. The outlet of this gland (*ductus pancreaticus*), through which the pancreatic juice passes into the gall-intestine, seems to be at first simple and single; afterwards it is often double.

The last section of the intestinal tube, the terminal intestine or large intestine (*epigaster*), in mammalian embryos, is, at first, a very simple, short, and straight tube, opening posteriorly through the anus. In the lower Vertebrates it retains this form throughout life. In Mammals, on the other hand, it grows to a considerable size, coils, and differentiates into different sections, of which the foremost and longest is called the colon, the shorter and hinder the rectum. At the commencement of the former a valve (*valvula Bauhini*) forms, which divides the large intestine from the small intestine; behind appears a pouch-like protuberance, which grows larger and becomes the blind-intestine (*cæcum*) (Fig. 288, *v*). In plant-eating Mammals this becomes very large, while in those which eat flesh it remains very small, or is entirely aborted. In Man, as in most Apes, the beginning of the blind intestine alone becomes wide; its blind end remains very narrow, and afterwards appears only as a useless appendage of the former. This "vermal appendage" is interesting in dysteleology as a rudimentary organ. Its only importance in Man consists in the fact that now and then a raisin-stone, or some other hard, indigestible particle of food becomes lodged in its narrow cavity, causing inflammation and suppuration, and, consequently, killing individuals otherwise perfectly healthy. In our plant-eating ancestors this rudimentary organ was larger, and was of physiological value.

Finally, we must mention another important appendage of the intestinal tube; this is the urinary bladder (*urocystis*) with the urinary tube (*urethra*), which in development and in morphological character belong to the intestinal system. These urinary organs, which act as receptacles and excretory passages for the urine secreted by the kidneys, originate from the inner part of the allantois-stalk. The allantois develops, as a sac-like protuberance, from the anterior wall of the last section of the intestine (Fig. 286, *u*). In the Dipneusta and Amphibia, in which this blind-sac first appears, it remains within the body-cavity (*cœloma*), and acts entirely as a urinary bladder. In all Amniota, on the other hand, it protrudes considerably out of the body-cavity of the embryo, and forms the large embryonic "primitive urinary sac," which, in higher Mammals, forms the placenta. At birth this is lost; but the long allantois-stalk (*r*) remains, its upper portion forming the central navel band of the urinary vesicle (*ligamentum vesico-umbilicale medium*), a rudimentary organ which extends as a solid cord from the top of the urinary bladder to the navel. The lower part of the allantois-pedicle (the "*urachus*") remains hollow, and forms the urinary bladder. At first, in Man, as in the lower Vertebrates, this organ discharges into the last section of the posterior intestine, and there is, therefore, a true "cloaca," receiving both urine and excrement; but, among the Mammals, this cloaca is permanent only in the Cloacal Animals, or Monotremes, as in Birds, Reptiles, and Amphibia. In all other Mammals (*Marsupialia* and *Placentalia*) a transverse partition forms at a later period, and separates the urinary-sexual aperture in front from the anal aperture behind. (Cf. Chapter XXV.)

EXPLANATION OF PLATE I.—(FRONTISPIECE.)

DEVELOPMENT OF THE FACE.

The twelve figures in Plate I. represent the faces of four different Mammals in three distinct stages of individual evolution: MI–MIII that of Man, BI–BIII of the Bat, CI–CIII of the Cat, SI–SIII of the Sheep. The three different stages of evolution have been chosen to correspond as far as possible; they have been reduced to about the same size, and are seen from in front. In all the figures the letters indicate the same: *a*, eye; *v*, fore-brain; *m*, mid-brain; *s*, frontal process; *k*, nose-roof; *o*, upper jaw process (of the first gill-arch); *u*, lower jaw process (of the first gill-arch); *h*, second gill-arch; *d*, third gill-arch; *r*, fourth gill-arch; *g*, ear-fissure (remains of the front gill-opening); *z*, tongue. (Cf. Plates VI. and VII., Figs. 232–236, p. 243; also Figs. 123, 124, vol. i. p. 370.)

TABLE XXXVII.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE HUMAN INTESTINAL SYSTEM.

I. *First Period: Intestine of Gastræa* (Figs. 274–277; Plate V. Figs. 9, 10).

The whole intestinal system is a simple pouch (primitive intestine), the simple cavity of which has one orifice (the primitive mouth).

II. *Second Period: Intestine of the Scolecida* (Plate V. Fig. 11).

The simple intestinal tube widens in the middle into the stomach, and acquires, at the end opposite to the primitive mouth, a second opening (primitive anus); as in the lower Worms.

III. *Third Period: Intestine of Chorda Animals* (Fig. 281; Plate V. Fig. 12).

The intestinal tube differentiates into two main sections—the respiratory intestine with gill-openings (gill-intestine) in front, the digestive intestine with stomach-cavity (stomach-intestine) behind; as in Ascidia.

IV. *Fourth Period: Intestine of Skull-less Animals (Acrania)* (Fig. 282; Plate XI. Fig. 15).

The gill-streaks appear between the gill-openings of the respiratory intestine; a liver blind-sac grows from the stomach-pouch of the digestive intestine; as in the Amphioxus.

V. *Fifth Period: Intestine of Cyclostoma* (Plate XI. Fig. 16).

The thyroid gland develops from the ciliated groove on the base of the gills (hypobranchial groove). A compact liver-gland develops from the liver blind-sac.

VI. *Sixth Period: Intestine of Primitive Fishes* (p. 114).

Cartilaginous gill-arches appear between the gill-openings. The foremost of these form the lip-cartilages and the jaw-skeleton (upper and lower jaw). The swimming-bladder grows from the pharynx. The ventral-salivary gland appears near the liver, as in Selachii.

VII. *Seventh Period: Intestine of Dipneusta* (p. 118).

The swimming-bladder modifies into the lungs. The mouth-cavity becomes connected with the nose-cavity. The urinary bladder grows from the last section of the intestine, as in Lepidosiren.

VIII. *Eighth Period: Intestine of Amphibia* (p. 126).

The gill-openings close. The gills are lost. The larynx originates from the upper end of the trachea.

IX. *Ninth Period: Intestine of Monotremes* (p. 145).

The primitive mouth and nasal cavity is separated by the horizontal palate-roof into the lower mouth-cavity (food passage) and the upper nose-cavity (air passage); as in all Amnion Animals.

X. *Tenth Period: Intestine of Marsupials* (p. 149).

The existing cloaca is separated by a partition wall into an anterior urinary-sexual aperture and a posterior anal aperture.

XI. *Eleventh Period: Intestine of Catarhine Apes* (p. 176).

All parts of the intestine, and especially the teeth-apparatus, acquire the characteristic development common to Man and Catarhine Apes.

CHAPTER XXIV.

DEVELOPMENT OF THE VASCULAR SYSTEM.

Application of the Fundamental Law of Biogeny.—The Two Sides.—Heredity of Conservative Organs.—Adaptation of Progressive Organs.—Ontogeny and Comparative Anatomy complementary of each other.—New "Theories of Evolution" of His.—The "Envelope Theory" and the "Waste-rag Theory."—Main Germ and Supplementary Germ.—Formative Yelk and Nutritive Yelk.—Phylogenetic Origin of the latter from the Primitive Intestine.—Origin of the Vascular System from the Vascular Layer, or Intestinal-fibrous Layer.—Phylogenetic Significance of the Ontogenetic Succession of the Organ-systems and Tissues.—Deviation from the Original Sequence; Ontogenetic Heterochronism.—Covering Tissue.—Connective Tissue.—Nerve-muscle Tissue.—Vascular Tissue.—Relative Age of the Vascular System.—First Commencement of the Latter; Cœloma.—Dorsal Vessel and Ventral Vessel of Worms.—Simple Heart of Ascidia.—Atrophy of the Heart in the Amphioxus.—Two-chambered Heart of the Cyclostoma.—Arterial Arches of the Selachii.—Double Auricle in Dipneusta and Amphibia.—Double Ventricle in Birds and Mammals.—Arterial Arches in Birds and Mammals. Germ-history (Ontogeny) of the Human Heart.—Parallelism of the Tribal-history (Phylogeny).

"Morphological comparison of the adult conditions should naturally precede the study of the earliest conditions. Only in this way can the investigation of the history of development proceed in a definite direction; it is thus provided, as it were, to see each step in the formative process in its true relation with the condition which is finally to be reached. Treatment of the history of development without preparatory study is only too likely to lead to groping in the dark; and it not infrequently leads to the most unfortunate results—far inferior to those which might be established beyond question without any study of the history of development."—ALEXANDER BRAUN (1872).

IN applying to Organogeny the fundamental law of Biogeny, we have already afforded some conception of the degree in which we may follow its guidance in the study of tribal history. The degree differs greatly in the different organ-systems; this is so, because the capacity for transmission on one side, and the capacity for modification on the other, vary greatly in the different organs. Some parts of the body cling tenaciously to the inherited germ-history; and, owing to heredity, accurately retain the mode of evolution inherited from primæval animal ancestors; other parts of the body, on the contrary, exhibit very small capacity for strict heredity, and have a great tendency to assume new kenogenetic forms by adaptation, and to modify the original Ontogeny. The former organs represent, in the many-celled community of the human organism, the constant or conservative; the latter, on the contrary, the changeable or progressive element of evolution. The mutual interaction of both elements determines the course of historical evolution.

Only to the conservative organs, in which Heredity preponderates over Adaptation, in the course of tribal evolution, can we directly apply the Ontogeny to the Phylogeny, and can infer, from the palingenetic modification of the germ-forms, the primæval metamorphosis of the tribal forms. In the progressive organs, on the contrary, in which Adaptation has acquired the ascendency over Heredity, the original course of evolution has, usually, been so changed, vitiated, and abbreviated, in the course of time, that we can gain but little certain information as to the tribal-history from the kenogenetic phenomena of their germ-history. Here, therefore, Comparative Anatomy must come to our help, and it often affords much more important and trustworthy disclosures as to Phylogeny than Ontogeny is able to impart. It is, therefore, most important, if the fundamental law of Biogeny is to be correctly and critically applied, to keep its two sides continually in view. The first half of this fundamental law of evolution enables us to use Phylogeny, as it shows us how to gain an approximate knowledge of the history of the tribe from that of the germ: the germ-form reproduces, by Heredity, the corresponding tribal form (Palingenesis). The other half of the law, however, limits this guiding principle, and calls attention to the foresight with which it must be employed; it shows us that the original reproduction of the Phylogeny in the Ontogeny has been in many ways altered, vitiated, and abbreviated, in the course of millions of years. The germ-form has deviated, by Adaptation, from the corresponding tribal form (Kenogenesis); the greater this deviation, the more are we compelled to employ Comparative Anatomy in the study of Phylogeny.

Perhaps in no other system of organs of the human body is this so greatly the case as in the vascular system (vascular, or circulatory apparatus), the development of which we will now examine. If we attempted to infer the original structural features of our older animal ancestors solely from the phenomena which the individual development of these organ-systems, in the embryo of Man and of other high Vertebrates, exhibit, we should obtain wholly erroneous views. By many influential embryonic adaptations, among which the development of an extensive nutritive yelk must be regarded as the most important, the original course of development of the vascular system has been so altered, vitiated, and abbreviated, in the higher Vertebrates, that no, or very little, trace of many of the most important phylogenetic features are retained in the Ontogeny. Such explanation as is afforded by the latter would be entirely useless to us if Comparative Anatomy did not lend its aid, and afford us the clearest guidance in our search for tribal history.

Comparative Anatomy is, therefore, especially important in helping us to understand the vascular system, and, equally, the skeleton system, so that, without its guidance, it is unsafe to take a single step in this difficult field. Positive proof of this assertion can be gained by studying the complex vascular system as explained in the classical works of Johannes Müller, Heinrich Rathke, and Karl Gegenbaur. An equally strong negative proof of the assertion is afforded by the ontogenetic works of Wilhelm His, an embryologist of Leipsic, who has no conception of Comparative Anatomy, nor consequently, of Phylogeny. In 1868, this industrious but uncritical worker published certain comprehensive "Studies of the First Rudiment of the Vertebrate Body," which are among the most wonderful productions in the entire literature of Ontogeny. As the author hopes to attain a "mechanical" theory of development by means of a most minute description of the germ-history of the Chick alone, without the slightest reference to Comparative Anatomy and Phylogeny, he falls into errors which are unparalleled in the whole literature of

Biology, rich as this unfortunately is in errors. Only in the magnificent germ-history of the Bombinator by Alexander Goette is incomprehensible nonsense and derision of every reasonable causal connection in evolution more nakedly set forth. (Cf. vol. i. pp. 65, 66.) His announces, as the final result of his investigations, "that a comparatively simple law of growth is the only essential in the first process of evolution. All formation, whether it consist in fission of layers, or in the formation of folds, or in complete articulation, results from this fundamental law." Unfortunately the author does not say in what this all-embracing "law of growth" really consists; just like other opponents of the theory of descent who substitute a great "law of evolution," without telling anything of its nature. From the study of the ontogenetic works of His, on the other hand, it soon becomes evident that he conceives form-constructing "Mother Nature" merely as a kind of clever dressmaker; by cutting out the germ-layers in various ways, by bending, folding, pulling, and splitting them, this clever sempstress easily brings into existence the various forms of animal species, by "development" (!). The bendings and foldings especially play the most important part. Not only the differentiation of head and trunk, of right and left, of central stem and periphery, but also the rudiment of the limbs, as also the articulation of the brain, the sense-organs, the primitive vertebral column, the heart, and the earliest intestines, can be shown, with convincing necessity (!) to be mechanical results of the first development of folds. Most grotesque is the mode in which the dressmaker proceeds in forming the two pairs of limbs. Their first form is determined by the crossing of four folds bordering the body, "like the four corners of a letter." Yet this wonderful "envelope theory" of the vertebrate limbs is surpassed by the "waste-rag theory" (Höllen-lappen Theorie) which His gives of the origin of the rudimentary organs: "Organs (like the hypophysis and the thyroid gland) to which no physiological part has yet been assigned, are embryonic remnants, comparable to the clippings, which in the cutting of a dress cannot be entirely avoided, even by the most economical use of the material" (!). Nature, therefore, in cutting out, throws the superfluous rags of tissue into the waste heap. Had our skull-less ancestors of the Silurian age had any presentiment of such aberrations of intellect of their too speculative human descendants, they would certainly have preferred relinquishing possession of the hypobranchial groove on the gill-body, instead of transmitting it to the extant Amphioxus, and of leaving a remnant of it to us, in the equally unsightly as useless thyroid gland. (Cf. p. 336).

It will probably be thought that the ontogenetic "discoveries" of His, which appear in a doubly comical light in consequence of the accompanying display of mathematical calculations, can only have occasioned momentary amusement in critical scientific circles. Far from it! Immediately after their appearance, they were not only much praised as the beginning of a new "mechanical" era in Ontogeny, but they have even yet numerous admirers and adherents, who seek to spread the scientific errors of His as far as possible. On this account, I have felt myself obliged to point out emphatically the complete falsity of these views. The vascular system affords especial occasion for this; for among the most important advances which His claims to have caused by his new conception of germ-history, is, according to him, his discovery that "the blood and tissue of the connective substance" (that is to say, the greatest part of the vascular system) "do not originate from the two primary germ-layers, as do all the other organs, but from the elements of the white yelk." The latter is designated as "supplementary yelk, or parablast," to distinguish it from the "main-germ, or archiblast" (the germ-disc composed of the two primary germ-layers).

The whole of this artificial development theory of His, and above all the unnatural distinction between the supplementary and the main germ, collapses like a card house when the Anatomy and Ontogeny of the Amphioxus, that invaluable lowest Vertebrate, is contemplated, which alone can elucidate the most difficult and darkest features in the development of the higher Vertebrates, and thus also of Man. The gastrula of the Amphioxus alone overthrows the whole artificial theory; for this gastrula teaches us that all the various organs and tissues of complete Vertebrates originally developed entirely from the two primary germ-layers. The developed Amphioxus, like all other Vertebrates, has a differentiated vascular system and a skeleton of "connective substance tissues" extending throughout its body, and yet there is in this case no "supplementary germ" from which these tissues can originate thus, contrasting with the other tissues.

The larvæ of the Amphioxus, arising from the original bell-gastrula (*archigastrula*), in its further development, throws the most important rays of light also upon the difficult history of development of the vascular system. In the first place, it answers the very important question, which we have already frequently indicated, as to the origin of the four secondary germ-layers; it clearly shows that the skin-fibrous layer originates from the exoderm, the intestinal-fibrous layer, on the contrary, in an analogous manner, from the entoderm of the gastrula; the cavity thus caused between the two fibrous layers is the first rudiment of the body-cavity, or the cœlom (Figs. 50, 51, vol. i. p. 236). As the Amphioxus larva thus shows that the fission of the layers is the same in the lowest Vertebrates as in the Worms, it at the same time represents the phylogenetic connection between the Worms and the higher Vertebrates. As, moreover, the primitive vascular stems in the Amphioxus originate in the intestinal wall, and in this, as in the embryos of all other Vertebrates, proceed from the intestinal-fibrous layer, proof is afforded us that the earlier embryologists were right in calling the latter the vascular layer. Finally, the Comparative Ontogeny of the different vertebrate classes further convinces us that the vascular layer is originally everywhere the same. The vascular system in Man, as in all Skulled Animals, forms a complex apparatus of cavities, which are filled with juices, or fluids, containing cells. The vessels play an important part in the nourishment of the body; some of them conduct the nutritive blood fluid round in the different parts of the body (blood-vessels); some collect the wasted juices and discharge them from the tissues (lymph-vessels). With the latter, the great "serous cavities" are also connected, especially the body-cavity, or cœloma. The heart, acting as a centre of motion for the regular circulation of the juices, is a strong muscular pouch, which contracts in regular pulsations, and is provided with valves, like those of a pump apparatus

This constant and regular circulation of the blood alone makes the complex change of substance with the higher animals possible.

Important as is the vascular system in the more highly developed and differentiated animal body, it is not, however, an apparatus as indispensable to animal life as is generally supposed. In the older theory of medicine the blood was regarded as the real source of life, and "humoral pathology" referred most diseases to "corrupt blood-mixture." Similarly, the blood plays the most important part in the prevailing, obscure conception of Heredity. Just as half-blood, pure blood, etc., etc., are yet common phrases, so it is widely believed that the transmission, by Heredity, of definite morphological and physiological characters from the parent to the child "lies in the blood." That this customary notion is entirely false, is easily seen from the fact that, neither in the act of procreation is the blood of the parents directly transmitted to the procreated germ, nor does the embryo acquire blood at an early period. As we have already seen, not only the separation of the four secondary germ-layers, but also the beginning of the most important organs, takes place, in the embryos of all Vertebrates, before the rudiment of the vascular systems, of the heart and blood, is formed. In accordance with this ontogenetic fact, we must, from a phylogenetic point of view, regard the vascular system as the most recent, the intestinal system, on the contrary, as the oldest formation of the animal body. The origin of the vascular system is, at least, much later than that of the intestinal system. If the fundamental law of Biogeny is rightly appreciated, it is possible, from the ontogenetic sequence, in which the various organs of the animal body consecutively originate in the embryo, approximately to infer the phylogenetic sequence, in which these organs gradually developed, one after the other, in the ancestral line of animals. In the "Gastræa theory" I made the first attempt to establish the phylogenetic significance of the ontogenetic sequence of the organ-systems; but it must be remarked that this sequence is not always identical in the higher animal tribes. In Vertebrates, and therefore also in our own ancestral line, the organ-systems may be ranged according to age, in something like the following order: I. The skin-system (*A*) and the intestinal system (*B*). II. The nerve (*C*) and muscular systems (*D*). III. The kidney system (*E*). IV. The vascular system (*F*). V. The skeleton system (*G*). VI. The sexual system (*H*). (Cf. Table XXXIX., p. 367.)

In the first place, the gastrula proves that in all animals with the exception of the Primitive Animals (*Protozoa*),—therefore, in all Intestinal Animals (*Metazoa*),—two primary organ-systems originally arose simultaneously and first; these were the skin-system (skin-covering) and the intestinal system (stomach-pouch). The first is represented, in its earliest and simplest form, by the skin-layer or exoderm, the latter by the intestinal layer or entoderm of the Gastræa. As we can ascribe the same origin, and, therefore, also the same morphological significance, to these two primary germ-layers in all Intestinal Animals, from the simplest Sponge to Man, the homology of these two layers seems sufficient proof of the above assumption.

Immediately after the differentiation of the two primary germ-layers, an inner or outer skeleton develops in many lower animals (*e.g.*, in Sponges, Corals, and other Plant

Animals). In the ancestors of Vertebrates, the development of the skeleton did not take place till much later, in the Chorda Animals (*Chordonia*). In them, after the skin-system and the intestinal system, two other organ-systems simultaneously arise; these are the nervous and the muscular systems. The way in which these two organ-systems which mutually condition each other, developed simultaneously and independently, in reciprocal action and yet in opposition to each other, was first explained by Nicholaus Kleinenberg in his excellent monograph on the Hydra, the common fresh-water Polyp.[190] In this interesting little animal, single cells of the skin-layer send fibre-shaped processes inward, which acquire the power of contraction, the capacity, characteristic of the muscles, of contracting in a constant direction. The outer, roundish part of the exoderm cell remains sensitive and acts as the nervous element, the inner, fibre-shaped part of the same cell becomes contractile, and, incited to contraction by the former part, acts as the muscular element (Fig. 293). These remarkable neuro-muscular cells thus still unite in a single individual of the first order the functions of two organ-systems. One step further; the inner, muscular half of the neuro-muscular cell (Fig. 293, *m*) acquires its own nucleus, and separates from the outer, nervous half (*n*), and both organ-systems have their independent element of form. The fission of the muscular skin-fibrous layer from the nervous skin-sensory layer in embryonic Worms confirms this important phylogenetic process (Figs. 50, 51, vol. i. p. 236).

These four organ-systems, which have been mentioned, were already in existence, when an apparatus developed, tertiarily, in the human ancestral line, which, at first sight, seems of subordinate significance, but which proves, by its early appearance in the animal series and in the embryo, that it must be very ancient and, consequently, of great physiological and morphological value. This is the urinary apparatus, or kidney system, the organ-system which secretes and removes the useless fluids from the body. We have already seen how soon the primitive kidneys appear in the embryo of all Vertebrates, long before any trace of the heart is discoverable. Correspondingly, we also find a pair of simple primitive kidney ducts (the so-called excretory ducts or lymphatic vessels) almost universally diffused in the Worm tribe, which is so rich in forms. Even the lowest classes of Worms, which have as yet neither body-cavity nor vascular system, are furnished with these primitive kidneys (Fig. 280, *nc*, p. 327). It was only in the fourth place, after the kidney system, that the vascular system developed in our invertebrate ancestors; this is plainly shown in the Comparative Anatomy of Worms. The lower Worms (*Acœlomi*) possess no part of the vascular system, no body-cavity, no blood, no heart, and no vessels; this is the case, for example, in the comprehensive group of the Flat Worms (*Plathelminthes*), the Gliding Worms (*Turbellaria*), the Sucking Worms (*Trematoda*), and the Tape Worms. In the higher Worms, which are therefore called Cœlomati, a body-cavity (*cœloma*), filled with blood, first begins to form; and, side by side with this, special blood-vessels then also develop. These features have been transmitted from the Cœlomati to the four higher animal tribes.

These organ-systems are common to Vertebrates and to the three higher animal tribes, the Articulated Animals

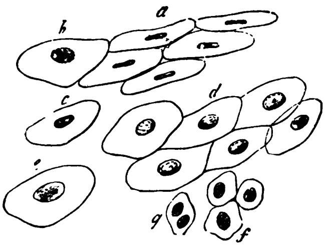
(*Arthropoda*), the Soft-bodied Animals (*Mollusca*), and the Star Animals (*Echinoderma*), and we may, therefore, infer that they have all acquired these, as a common inheritance from the Cœlomati; but we now meet with a passive apparatus of movement, the skeleton system, which, in this form, is exclusively peculiar to Vertebrates. Only the very first rudiment of this, the simple notochord, is found in Ascidia, which are the nearest invertebrate blood-relations of Vertebrates. We infer from this, that the common ancestors of both, the Chorda Animals, did not branch off from the Worms till a comparatively late period. The notochord is, it is true, one of those organs which appear at a very early period in the vertebrate embryo; but this is clearly due to an ontogenetic heterochronism, to displacement in time in the germ-history, that is, a gradual disarrangement in the original phylogenetic sequence, caused by embryonic adaptation. On Comparative Anatomical grounds it may safely be assumed, that the first origin of the skeleton system did not precede, but followed that of the kidney system and of the vascular system, although Ontogeny appears to indicate the contrary.

Last of all the organ-systems, the sexual system finally developed, in the sixth place, in our ancestors; of course it must be understood that this was last, in the sense that the sexual apparatus acquired the independent form of a special organ-system subsequently to all the other organs. The simplest form, that of reproductive cells, is certainly very ancient. Not only the lowest Worms and Plant Animals propagate sexually, but this was also probably the case in the common parent-form of all Metazoa, in the Gastræa; but in all these low animals, the reproductive cells do not constitute special sexual organs in a morphological sense; they are rather, as we shall soon see, simple component parts of other organs.

Like the organ-systems of the human body, the tissues, which compose these systems, are of different ages and of varying morphological value. As we were justified in drawing an inference as to the phylogenetic sequence in age of the organ-systems, from the ontogenetic sequence in which they successively appear in the embryo, so are we justified in inferring the order in which the tissues originated during the course of tribal history, from the sequence of the stages in germ-history. The result of this is a phylogenetic classification (Table XXXVIII.) of the tissues of the human body, similar to that of the organs (Table XXXIX., p. 367).

The tissues of the human body, arising by division of labour, the separation and the connection of the component cells, may be distributed, with reference to their development, in the four following distinct groups:—1, covering-tissue (*epithelium*); 2, connective tissue (*connectivum*); 3, nerve and muscular tissue (*neuro-musculum*); and 4, vascular tissue (*vasalium*). Of these, in accordance with the Gastræa theory, we must regard the covering-tissue as the oldest and most original form, as the actual primary or primitive tissue; the three other main forms must, on the other hand, be considered as secondary or derived forms, which developed at a later period from the covering-tissue; the connecting-tissue first, then the neuro-muscular, and lastly the vascular tissue.

The oldest and most original form of tissue is, undoubtedly, the covering-tissue (*epithelium*), the cells of which are arranged in a simple strata-like way, and extend over the outer and inner surface of the body as a protective and secreting cover. This is proved by the simple fact that the formation of the tissues of the animal body begins with the formation of the gastrula, and that the latter itself consists solely of two simple epithelial strata, of the skin-layer (Fig. 274, *e*), and of the intestinal-layer (*i*). Histologically, the two primary germ-layers are simple epithelia. When these, afterwards, separate into the four secondary germ-layers, the skin-sensory layer becomes the outermost of the external coverings (dermal-epithelium); the intestinal-glandular layer becomes the innermost of the internal coverings (gastral-epithelium). The tissue of the outer skin and of all its appendages, such as nails (Fig. 289),



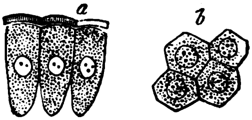
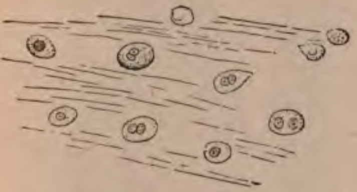


FIG. 289.—Tissue of the nails (flattened epithelium): *a–e*, cells of the upper strata; *f*, *g*, cells of the lower strata.

FIG. 290.—Tissue of the covering of the small intestine (columnar epithelium): *a*, side view of three cells (with thicker, porous borders); *b*, surface view of four cells. (After Frey.)

hairs, skin-glands, etc., arise from the skin-sensory layer. (Cf. Table XXIX., p. 232.) The inner covering of the intestinal tube and of its intestinal glands originates, on the other hand, from the intestinal-glandular layer (Fig. 290).

Connective tissue (*connectivum*) must be regarded as forming, in order of phylogenetic age, the second main group of tissues. This is morphologically characterized by the intercellular substance, which develops between the cells, physiologically, by the double part which it plays, as connecting substance and as complementary substance between the other tissues, as an inner supporting substance and as a protective covering for the inner organs. Of the numerous forms and varieties of connective tissue, we regard the jelly-like tissue (Fig. 291 : Fig. 6, vol. i. p. 126), the fatty tissue, and the chorda tissue as the earlier; the fibrous, cartilaginous (Fig. 292), and bone-tissue (Fig. 5, vol. i. p. 126) as the more recent formations. All these various forms of connective tissue are products of the middle germ-layer, or mesoderm ; or, more accurately, of the two fibrous layers, of which the skin-fibrous layer is originally derived from the exoderm, the intestinal-fibrous layer from the entoderm.



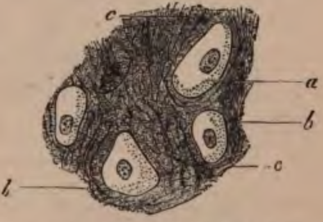


FIG. 291.—Jelly-like tissue from the vitreous body of an embryo of four months (round cells as jelly-like intercellular substance).

FIG. 292.—Cartilage-tissue of the fibrous or netted cartilage of the ear-shell : *a*, cells ; *b*, intercellular mass ; *c*, fibres in the latter. (After Frey.)

The nerve-muscular tissue (*neuro-musculum*) is of much more recent origin than the connective tissue. If epithelial tissue represents a primary period in tribal history, and connective tissue a secondary period, then we may characterize a third, much later period, by nerve-muscle tissu

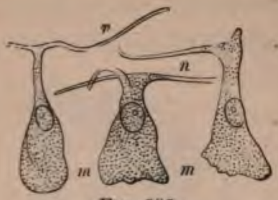
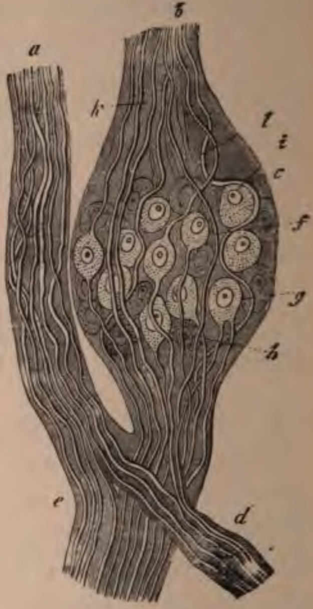


FIG. 293.



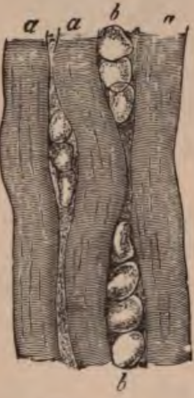


FIG. 295.

FIG. 294.

FIG. 293.—Nerve-muscle tissue. Three cells from Hydra: *n*, out nervous; *m*, inner, muscular part of the cells. (After Kleinenberg.)

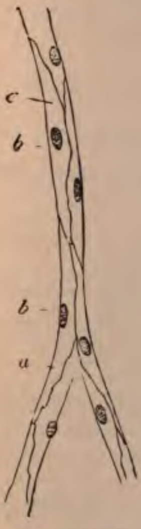
FIG. 294.—Nerve-tissue (from a spinal nerve knot): *a*, anterior, posterior root of the spinal nerve; *d*, *e*, fibrous nerve-stem; *f*, *g*, *h*, *i*, ner cells in ganglion (*f*, unipolar, *g*, *h*, bipolar cells); *k*, *l*, nerve fibres. (Af Frey.)

FIG. 295.—Muscle-tissue. Three pieces of striped muscle fibre (*a*). terfibrous fat-cells (*b*). (After Frey.)

For while in the lowest Plant Animals the body consis merely of covering tissue, and while in many oth

Zoophytes a middle layer of connective tissue develops between the two primary germ-layers, it is only in the most highly developed Plant Animals that muscle and nerve tissue is formed. As has already been said, the latter first appeared as a common nerve and muscle tissue (*neuro-musculum*, Fig. 293; cf. p. 358). It was only afterwards that the muscle-tissue (Fig. 295) separated from the nerve-tissue (Fig. 294). The greater part of the nerve-tissue is derived from the skin-sensory layer, the greater part of the muscle-tissue from the skin-fibrous layer.

Vascular tissue (*vasalium*) must be regarded as forming



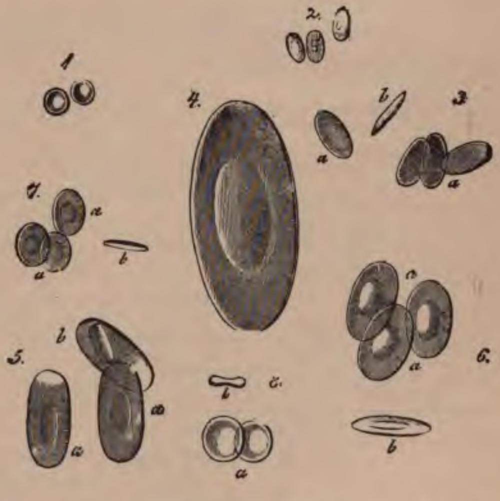


FIG. 296.—Vascular tissue (*vasalium*). A hair-vessel from the mesentery: *a*, vascular cells; *b*, the kernels of these ("endothelium").

FIG. 297.—Red blood cells (corpuscles) of various Vertebrates (equally magnified): 1, Human; 2, Camel; 3, Pigeon; 4, Proteus (p. 129); 5, Water-salamander (*Triton*); 6, Frog; 7, Fish (*Cobitis*); 8, Lamprey (*Petromyzon*); *a*, surface view; *b*, edge view. (After Wagner.)

TABLE XXXVIII.

Systematic Survey of the Sequence, according to Age, of the Human Tissue-groups.

(Phylogenetic Classification of Vertebrate Tissues.)

FIRST GROUP: PRIMARY TISSUES (*Epithelium*).

1. First Histological Stage of Evolution.

I. Covering-tissue (*Epithelium*).

I. *A*. Skin-covering tissue (*Epithelium dermale*) Skin-layer, or Exoderm, of Gastrula (afterwards skin-sensory layer)	1. Outer skin (*Epidermis*) 2. Glands of outer skin 3. (Earliest site of origin of the sperm-cells ?)
I. *B*. Intestinal covering tissue (*Epithel. gastrale*). Intestinal layer, or Entoderm, of Gastrula (afterwards the intestinal-glandular layer)	1. Real intestinal epithelium 2. Epithelium of the intestinal glands 3. (Earliest site of origin of egg-cell ?)

SECOND GROUP: SECONDARY TISSUES.

(All derived from the Covering-tissue, or Epithelium.)

2. Second Histological Stage of Evolution.

II. Connective-tissue (*Connectivum*).

II. *C*. Filling-up tissue (*Tela conjunctiva*) (softer [surrounding] connective tissue)	1. Jelly-like tissue 2. Fatty tissue 3. Fibrous tissue
II. *D*. Supporting tissue (*Tela skeletalis*) (firmer [supporting] connective tissue)	4. Chorda tissue 5. Cartilaginous tissue 6. Bone-tissue

3. Third Histological Stage of Evolution.

III. Nerve-muscle Tissue (*Neuro-musculum*).

III. *E*. Nerve-tissue (*Tela nervea*). Original outer portion of the nerve-muscle cells of the Exoderm	1. Nerve-cells (Ganglion-cells)	1. *a*. Peripheric nerve-cells (Rod-cells of the sense-organs) 1. *b* Central nerve-cells (mind-cells)
	2. Nerve-fibres (Nerve-tubes)	2. *a*. Sheathless nerve-fibres (pale, or medulla-less fibres) 2. *b*. Sheathed nerve-fibres (dark fibres, with medulla)
III. *F*. Muscle-tissue (*Tela muscularis*) Original inner portion of the nerve-muscle cells of the Exoderm	1. One-celled muscle-fibres	1. *a*. Smooth contractile fibre-cells 1 *b*. Striped contractile fibre-cells
	2. Many-celled muscle-fibres	2. *a*. Smooth muscle-masses 2. *b*. Striped muscle-masses

4. Fourth Histological Stage of Evolution.

IV. Vascular Tissue (*Vasalium*).

IV. *G*. Vascular lining tissue (*Tela vasalis*). Inner wall-covering of the Cœlom system	1. Cœlarium (Cœlom-epithelium)	1. *a*. Exocœlarium (Parietal Cœlom-epithelium) (and secondary site of origin of the sperm-cells ?) 1 *b*. Endocœlarium (Visceral cœlom-epithelium) (and secondary site of origin of the egg-cells ?)
	2 Endothelium (Vascular epithelium)	2. *a*. Endothelium of the lymph-vessels 2. *b*. Endothelium of the blood-vessels
IV. *H*. Lymph-tissue (*Tela lymphatica*). Liquid contents of the Cœlom system	1. Lymph (Colourless blood-cells and fluid intercellular substance) 2. Blood (Red blood-cells and fluid intercellular substance)	

TABLE XXXIX.

Systematic Survey of the Sequence, according to Age, of the Human Organ-systems.

(Phylogenetic Classification of Vertebrate Organs.)

(On the right are given the Ancestral Stages, in which the respective organs probably first appeared.)

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1. FIRST STAGE IN THE EVOLUTION OF ORGANS.

I. Skin and Intestinal Systems.

The two Systems appear first, and simultaneously, in the Gastread ancestors.

I. *A.* Skin-system (*Systema dermale*)	*A* 1. Simple exoderm	Gastræads
	A 2. Outer skin (Skin-sensory layer) and leather skin (Skin-fibrous layer)	Worms
	A 3. Outer skin, with hairs, glands, etc.	Mammals
I. *B.* Intestinal system (*Systema gastrale*)	*B* 1. Simple entoderm	Gastræads
	B 2. Intestinal epithelium (Intestinal-glandular layer) and intestinal muscular skin (Intestinal-fibrous layer)	Worms
	B 3. Gill-intestine and stomach-intestine	Chorda-animals

---

2. SECOND STAGE IN THE EVOLUTION OF ORGANS.

II. Nerve and Muscle Systems.

The two Systems appear first, and simultaneously, in the Primitive Worm ancestors.

II. *C.* Nerve-system (*Systema nerveum*)	*C* 1. Upper throat ganglia	Primitive Worms
	C 2. Simple medullary tube	Chorda-animals
	C 3. Brain and spinal marrow	Monorhina
II. *D.* Muscle-system (*Systema muscalare*)	*D* 1. Skin-muscle pouch	Primitive Worms
	D 2. Side muscles of the trunk	Acrania
	D 3. Trunk and limb muscles	Fishes

---

3. THIRD STAGE IN THE EVOLUTION OF ORGANS.

III. Kidney and Vascular Systems.

The two Systems first appear, one after the other, in the Soft-worm ancestors (*Scolecida*).

III. *E.* Kidney-system (*Systema renale*)	*E* 1. Primitive kidney canals	Scolecida
	E 2. Segmental canals	Acrania?
	E 3. Primitive kidneys	Monorhina
	E 4. Permanent kidneys	Protamnia
III. *F.* Vascular system (*Systema vasculare*)	*F* 1. Simple cœlom	Scolecida
	F 2. Dorsal and ventral vessels	Worms
	F 3. Heart (part of the ventral vessel)	Chorda-animals
	F 4. Heart, with auricle and ventricle	Monorhina

---

4. FOURTH STAGE IN THE EVOLUTION OF ORGANS.

IV. Skeleton and Sexual Systems.

The two Systems first appear, one after the other, in the Chordonia-ancestors.

IV. *G.* Skeleton-system (*Systema skeletare*)	*G* 1. Simple notochord	Chorda-animals
	G 2. Cartilaginous primitive skull	Monorhina
	G 3. Gill-arches, ribs, limbs	Selachii
	G 4. Limbs, with five digits	Amphibia
IV. *H.* Sexual system (*Systema sexuale*)	*H* 1. Simple hermaphrodite glands	Chorda-animals
	H 2. Distinct testes and ovaries	Acrania
	H 3. Seed-duct and oviduct	Selachii
	H 4. Phallus (penis, clitoris)	Protamnia

the most recent group of tissues, that which originated last Under this name are included those epithelial-like tissues which line the closed inner cavities of the body (the cœlom, chest-cavity, ventral cavity, heart-cavity, blood-vessels, etc (Fig. 296). In addition to this vascular carpet (endothelium), the liquids containing cells, which fill these cavities (lymph, blood, serum, etc.), must be classed with this tissue (Fig. 297). All these tissues may be grouped as vasalia. His wrongly ascribed to them a quite different, "parablastic" origin (from the nutritive yelk); they are, however, products of the intestinal-fibrous layer (and partly, perhaps, of the skin-fibrous layer). As the cœloma and the whole vascular system is of more recent phylogenetic origin, its peculiar tissues must also be more recent.

This phylogenetic explanation of the ontogenetic succession of the tissues and of the organ systems arising from them, appears to me to be satisfactorily proved by Comparative Anatomy, and by the Gastræa theory. If it is correct, it discloses an interesting glimpse into the entirely various age of the most important constituent parts of our body. The human skin and intestine are, according to this, many thousands of years older than the muscles and nerves; these again are much more ancient than kidneys and blood-vessels, and the latter, finally, are many thousands of years older than the skeleton and the sexual organs. The common view, that the vascular system is one of the most important and original organ-systems, is, therefore, erroneous; it is as false as the assumption of Aristotle that the heart is the first part to form in the incubated chick. On the contrary, all lower Intestinal Animals show plainly that the historic evolution of the vascular system did not begin till a comparatively late period. Not only all Plant Animals (Sponges, Corals, Hydropolyps, Medusæ), but also all lower Worms (*Acœlomi*), are entirely destitute of vascular system. In both groups, the fluid acquired by digestion is conveyed directly from the intestinal tube, through processes of this latter (the gastro-canals), into the different parts of the body. It is only in the intermediate and higher Worms that the vascular system first begins to develop, in consequence of the formation of a simple cavity (*cœloma*), or of a system of connected spaces, round the intestinal tube, in which cavities the nutritive fluid (blood) exuded through the intestinal wall, collects.

In the human ancestral line we meet with this first rudiment of the vascular system in that group of Worms which we spoke of as Soft Worms (*Scolecida*; p. 85). The Soft Worms, as we said, formed a series of intermediate stages between the lowest bloodless Primitive Worms (*Archelminthes*) and the Chorda-worms (*Chordonia*), which are already provided with a vascular system and a notochord. The vascular system must have begun, in the older Scolecida, with a very simple cœlom, a "body-cavity," filled with blood, and which surrounded the intestinal tube. Its origin was probably due to the accumulation of nutritive fluid in a cleft between the intestinal-fibrous layer and the skin-fibrous layer. A vascular system in this simplest form is yet found in the Moss-polyps (*Bryozoa*) in the Wheel-animalcule (*Rotatoria*), and in other lower Worms. The inner, visceral, part of the wall of the cœlom is, naturally, formed by the intestinal-fibrous layer (*endocœlar*), the outer, parietal, part by the skin-fibrous layer (*exocœlar*). The cœlom fluid, collected between the two, may contain detached cells (lymph-cells) from either fibrous layer.

A first advance in the development of this most primitive vascular system was accomplished by the formation of canals or blood-conducting tubes, which developed, independently of the cœloma, in the intestinal wall, that is, in the intestinal-fibrous layer of the wall. These real blood-vessels, in the stricter sense, appear in very different form in Worms of the intermediate and higher groups; sometimes they are very simple, sometimes very complex. Two primordial "primitive vessels" must be regarded as representing that form, which probably formed the first of the more complex vascular system of Vertebrates; these are a dorsal vessel, which passes from front to back along the middle line of the dorsal wall of the intestine, and a ventral vessel which passes, in the same direction, along the middle line of the ventral wall. Both at the front and at the back these two vessels are linked together by a loop surrounding the intestines. The blood enclosed in the two tubes is driven forward by the peristaltic contraction of this.

The further development of this simplest rudimentary blood-vessel system is evident in the class of the Ringed Worms (*Annelida*), in which we find it in very various stages of development. In the first place, many transverse connections probably arose between the dorsal and ventral vessels, so as to encircle the intestine (Fig. 298). Other vessels then penetrated into the body-wall and branched, so as to conduct blood to this part. As in those ancestral Worms, which we have called Chordonia, the front section of the intestine changed into a gill-body, these ascular loops, within the wall of this gill-body, which passed from the ventral vessel to the dorsal vessel, became modified into respiratory gill-vessels. Even at the present day, the organization of the remarkable Acorn-worm (*Balanoglossus*) exhibits a similar condition of gill-circulation (Fig. 186, p. 86).

A further important advance is exhibited, among extant Worms, in the Ascidia, which must be regarded as the nearest blood-relations to our primitive Chordonia ancestors. In these we find, for the first time, a real heart, that is, a *central organ of the circulation of the blood*, by the pulsating contractions of the muscular wall of which the blood is driven forward in the vascular tubes. The heart appears here in the simplest form, as a spindle-shaped pouch which passes at both ends into a main vessel (Fig. 188, c. p. 90; Plate XI. Fig. 14, *hz*). The original position of the heart on the ventral side, behind the gill-body of the Ascidian, plainly shows that it originated in a local dilation of a section of the ventral vessel. The alternating direction of the movements of the blood, which has already been mentioned, is remarkable; the heart expels the blood alternately through the anterior and through the posterior end. This is very suggestive, because in most Worms the blood

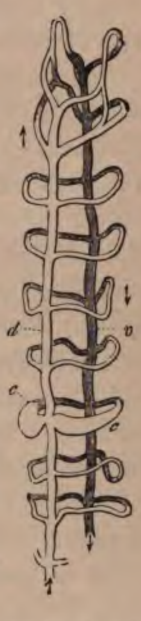


FIG. 298.—Blood-vessel system of a Ringed Worm (Saenuris); front section: *d*, dorsal vessel; *v*, ventral vessel; *c*, transverse connection between the two (enlarged like a heart). The arrows indicate the direction of the blood current. (After Gegenbaur.)

in the dorsal vessel moves from back to front, while in Vertebrates, on the contrary, it flows in the opposite direction, from front to back. As the heart of the Ascidian constantly alternates between these two opposite directions, it exhibits permanently, to a certain extent, the phylogenetic transition between the older direction of the dorsal blood-current toward the front in Worms, and the newer direction of the same toward the rear in Vertebrates.

As in the more recent Chorda Animals, which gave rise to the Vertebrate tribe, the newer direction became permanent, the two vessels which proceeded from the two ends of the heart-pouch, acquired a constant significance. The front section of the ventral vessel, since then, has steadily conducted the blood from the heart, acting, consequently, as an artery; the hinder section of the ventral vessel, on the contrary, leads the blood, circulating in the body, back into the heart, and must, therefore, be called a vein. In reference to their relation to the two sections of the intestine, we may speak of the latter, more accurately, as the intestinal vein, and of the former as the gill-artery. The blood contained in both vessels, which alone fills the heart also, is venous blood; that is, containing much carbonic acid. On the other hand, the blood which flows from the gills into the dorsal vessel is there refurnished with oxygen; is arterial blood. The most delicate branches of the arteries and veins pass into each other, within the tissue, through a network of extremely fine neutral hair-vessels or capillaries (Fig. 296).

If we now turn from the Ascidia to the nearest allied form, the Amphioxus, we are immediately surprised by an apparent retrogression in the development of the vascular system. The Amphioxus, as has been stated, has no real heart; but the blood is circulated in its vascular system by the main vascular stems themselves, which contract and pulsate along their whole length. (Cf. Fig. 151, vol. i. p. 420.) A dorsal vessel (aorta), situated over the intestine, absorbs the arterial blood from the gills and propels it through the body. The venous blood, in its return, collects in a ventral vessel (intestinal vein), situated under the intestine, and thus returns to the gills. Numerous vascular gill-arches, which accomplish respiration, and absorb oxygen from the water and emit carbonic acid, unite the ventral vessel with the dorsal vessel before. As, in Ascidia, that section of the ventral vessel which also forms the heart in Skulled Animals (*Craniota*), is already fully developed into a simple heart-pouch, we must regard the absence of the latter in the Amphioxus as the result of retrogression, as a reversion, in these Acrania, to the older form of vascular system, as it exists in Scolecida and many other Worms. We may assume that those Acrania which actually formed part of our ancestral line did not share this relapse, but rather inherited the one-chambered heart from the Chordonia and transmitted it directly to the older Skulled Animals (*Craniota*).

The Comparative Anatomy of Skulled Animals clearly exhibits the further phylogenetic development of the blood-vessel system. In the lowest stage of this group, in the Cyclostoma (p. 102), we first meet with a real lymph-vessel system, side by side with the blood-vessel system, a system of canals which collect the colourless fluid flowing from the tissues, and conduct it to the blood-current. Those lymph-vessels which absorb the milky, nutritive fluid, obtained directly by digestion, from the intestinal wall, and conduct it to the blood-current, are distinguishable as chyle-vessels, or "milky juice vessels." While the chyle, or milky juice, in consequence of the great amount of fat globules which it contains, appears milk white, the real lymph is colourless. The chyle, as well as the lymph, contain the same colourless amœboid cells (Fig. 9, vol. i. p. 132), which are also distributed in the blood as colourless blood-cells (corpuscles); the latter contains, in addition, the much greater quantity of red blood-cells (corpuscles), which gives the blood of Skulled Animals its red colour. The distinction, common to all Craniota, between lymph-vessels, chyle-vessels, and blood-vessels, is to be regarded as the result of a division of labour which took place between different portions of an original unitary, primitive blood-vessel system (or hæmolymph system).

The heart, the central organ of the circulation of the blood, which exists in all Craniota, also exhibits an advance in structure, even in the Cyclostoma. The simple spindle-shaped heart-pouch is separated into two divisions, or chambers, which are divided by two valves (Plate XI. Fig. 16, *hv*, *hk*). The posterior division, the fore chamber (*atrium*, *hv*), absorbs the venous blood from the veins of the body, and discharges it into the anterior division, the chamber, or main chamber (*ventriculus*, *hk*). From here it is propelled by the gill-artery stem (the foremost section of the ventral vessel) into the gills.

In Primitive Fishes (*Selachii*), an arterial stalk (*bulbus arteriosus*), separated by valves, originates, as a distinct section, from the foremost end of the ventricle. It forms the enlarged, hindmost end of the gill-artery stem (Fig

299, *abr*). From each side of this, from five to seven gill-arteries proceed; these rise between the gill-openings (*s*) to the gill-arches, encircle the throat, and combine above into a common aorta-stem, the continuation of which, passing backward above the intestine, corresponds to the dorsal vessel of Worms. As the arched arteries distribute themselves in a respiratory capillary net over the gill-arches, they thus contain venous blood in their lower part (as arterial gill-arches), and arterial blood in their upper part (as aorta-arches). The points at which separate aorta-arches unite, which occur on the right and left sides, are called aorta-roots. Of an originally greater number of aorta-arches, only five pairs are retained, and from these five (Fig. 300), in all higher Vertebrates, the most important parts of the arterial system develop.

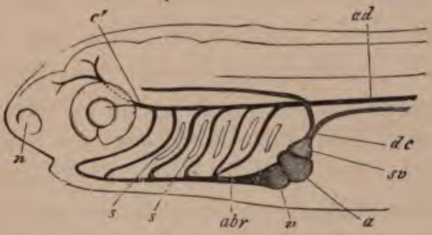
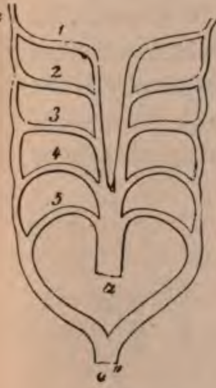
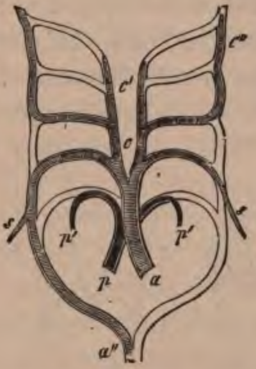


FIG. 299.—Head of an embryonic Fish, with the rudiment and the blood-vessel system; seen from the left side: *dc*, Cuverian duct (point of union of the front and hind main veins); *sv*, venous sinus (enlarged terminal portion of the Cuverian duct); *a*, auricle; *v*, main chamber; *abr*, gill-artery stem; *s*, gill-openings (between the arterial arches); *ad*, aorta; *c'*, head-artery (carotis); *n*, nose-groove. (After Gegenbaur.)

The appearance of the lungs, connected with the respiration of air, which first occurs in the Dipneusta, is most important in the further developement of the arterial system. In Dipneusta, the auricle of the heart separates into two halves by the formation of an incomplete partition. Only the right auricle now absorbs the venous blood of the body-veins. The left auricle, on the other hand, absorbs the arterial blood of the lung-veins; both auricles discharge in common into the simple ventricle, in which the two kinds of blood mingle, and are then propelled through the arterial stalk into the arterial arches. From the last of these latter spring the lung-arteries (Fig. 301, *p*); these convey a part of the mixed blood into the lungs, while the remainder is driven through the aorta into the body.

From the Dipneusta upward, we trace a progressive development of the vascular system, which finally leads, with the loss of gill respiration, to a complete separation of the two parts of the double circulatory system. In Amphibia, the partition between the two auricles becomes complete. In their young form, these yet retain gill-respiration and the circulatory system as in Fishes, and the heart contains only venous blood; at a later period, the lungs. with their vessels, are developed also, and the main chamber of the heart then contains mixed blood. In Protamnia and Reptiles, the main chamber and the arterial stalk belonging to it begin to separate, by the formation of a longitudinal partition, into two halves, and this partition becomes complete in the higher reptiles on the one side, in the parent-form of Mammals on the other. The right half of the heart alone now contains venous blood, the left half only arterial, as in all Birds and Mammals. The right auricle receives venous blood from the body-veins, and the right ventricle propels this through the lung-arteries into the lungs; from there it returns as arterial blood through the lung-veins to the left auricle, and is driven through the left ventricle into the body-arteries. Between the lung-arteries and lung-veins is situated the capillary system of the lesser, or lung-circulation; between the body-arteries and the body-veins lies the capillary system of the greater, or body-circulation. Only in the two highest Vertebrate





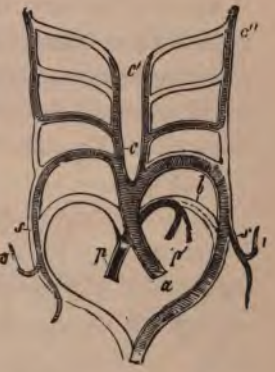


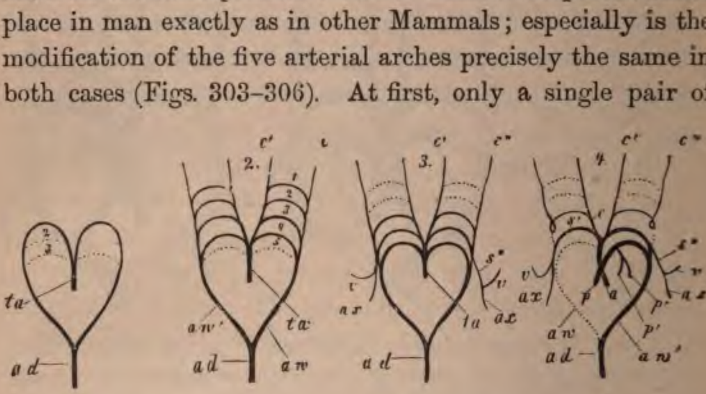
FIG. 300.—The five arterial arches of Skulled Animals (1–5) in their original form: *a*, arterial stalk; *a''*, main stem of the aorta; *c*, head-artery (carotis, anterior continuation of the aorta-roots). (After Rathke.)

FIG. 301.—The five arterial arches of Birds; the light portions of the rudiment disappear; only the dark parts are permanent. Letters as in Fig. 300: *s*, arteries of the clavicula (sub-clavian); *p*, lung-artery; *p'*, branches of the same. (After Rathke.)

FIG. 302.—The five arterial arches of Mammals. Letters as in Fig. 301: *v*, vertebral artery; *b*, Botalli's duct (open in the embryo, afterwards closed). (After Rathke.)

classes, in Birds and Mammals, is this complete separation of the two courses of the circulation perfect. Moreover, this separation has taken place in the two classes independently of each other, as is shown by the unequal development of the aortas. In Birds, which are descended from Reptiles, the right half of the fourth arterial arch has become the permanent arterial arch (*arcus aortæ*, Fig. 301). On the other hand, the latter has developed from the left half of the same arch (Fig. 302) in Mammals, which are directly descended from the Protamnia.

On comparing the arterial system in the various classes of the Skulled Animals (*Craniota*) in its matured condition, it appears in very various forms, and yet it develops, in all, from the same primitive form. This development takes place in man exactly as in other Mammals; especially is the modification of the five arterial arches precisely the same in both cases (Figs. 303–306). At first, only a single pair of arches develop, and these lie on the inner surface of the first pair of gill-arches (Figs. 147–150, vol. i. pp. 395–398; Fig. 303). A second and a third pair of arches then develop

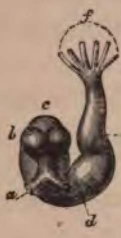


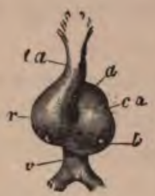
FIGS. 303–306.—Metamorphosis of the five arterial arches in the human embryo (diagram after Rathke): *ta*, arterial stalk; 1, 2, 3, 4, 5, the arterial arches from the first to the fifth pair; *ad*, main stem of the aorta; *aw*, roots of the aorta. In Fig. 303, three of the arterial arches are given; in Fig. 304, the whole five (those indicated by dots are not yet developed); in Fig. 305, the first two have again disappeared; in Fig. 306, the permanent arterial stems are represented. The dotted parts disappear. *s*, Sub-clavian artery; *v*, vertebral artery; *ax*, axillary artery; *c*, carotid artery (*c'*, outer, *c''*, inner carotis); *p*, pulmonary artery (lung-artery).

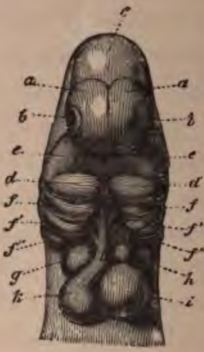
behind the first, and these are situated on the inner surface of the second and third gill-arches. At length, a fourth and a fifth pair appear behind the third (Fig. 304); but while the latter are developing, the first two are again disappearing by growing together (Fig. 305). The permanent main arteries develop only from the three posterior arterial arches (3, 4, 5, in Fig. 304), the lung-arteries from the last (*p*; Fig. 306). (Cf. with this Fig. 302.)

The human heart also (Fig. 314) develops exactly like that of other Mammals. We have already considered the first principles of its germ-history (vol. i. pp. 392–395, Figs. 143–147), which essentially corresponds with its Phylogeny.[191] We saw that the very first rudiment of the heart is a spindle-shaped thickening of the intestinal-fibrous layer in the ventral wall of the head-intestine (Fig. 143, *df*). This spindle-shaped formation then becomes hollow, forms a simple pouch, and separates from the place at which it originated, so that it then lies freely in the cardiac cavity (Figs. 145, 146). This pouch bends into the form of an S (Fig. 144, *c*), and, at the same time, turns spirally on an imaginary axis, so that the posterior part lies on the dorsal surface of the anterior part. The combined yelk-veins open into its posterior extremity; from the anterior extremity proceed the arterial arches (Fig. 150, vol. i. p. 398).

This first rudiment of the human heart, which encloses a very simple cavity, corresponds to the heart of the Ascidians, and must be regarded as a reproduction of the heart of the Chordonia; it now, however, separates into two, and then three parts, thus exhibiting for a very brief period the heart-structure of the Cyclostoma and of Fishes. The spiral turn and curve of the heart increases, and, simultaneously, two shallow transverse indentations of the circumference appear, which externally mark the three sections (Figs. 307, 308). The anterior section, which is turned toward the







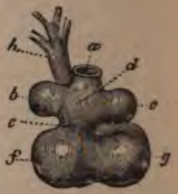


FIG. 307.—Heart of an embryonic Rabbit, from behind: *a*, yelk-veins; *b*, auriculæ; *c*, auricle (*atrium*); *d*, ventricle; *e*, artery-stalk; *f*, base of the three pairs of arterial arches. (After Bischoff.)

FIG. 308.—Heart of the same embryo (Fig. 307), from the front: *v*, yelk-veins; *a*, auricle; *ca*, auricular canal; *l*, left ventricle; *r*, right ventricle; *ta*, artery-stalk. (After Bischoff.)

FIG. 309.—Heart and head of an embryonic Dog, from the front: *a*, fore-brain; *b*, eyes; *c*, mid-brain; *d*, primitive lower jaw; *e*, primitive upper jaw; *f*, gill-arches; *g*, right auricle; *h*, left auricle; *i*, left ventricle; *k*, right ventricle. (After Bischoff.)

FIG. 310.—Heart of the same embryo, from behind: *a*, entrance of the yelk-veins; *b*, left auricular process; *c*, right auricular process; *d*, auricle; *e*, auricular canal; *f*, left ventricle; *g*, right ventricle; *h*, artery-stalk. (After Bischoff.)

ventral side, and from which the aortal arches spring, reproduces the arterial stalk (*bulbus arteriosus*) of the Selachii. The central section is the rudiment of a simple chamber, or ventricle (*ventriculus*); and the posterior section, the one turned toward the dorsal side, into which the yelk-veins open, is the rudiment of a simple auricle (*atrium*). The latter, like the simple auricle of the heart of the Fish, forms a pair of lateral protuberances, the heart ears, or auricular appendages (*auriculæ*, Fig. 307, *b*); and hence the indentation between the auricle and ventricle is called the auricular canal (*canalis auricularis*, Fig. 308, *ca*). The heart of the human embryo is now a complete Fish heart.

Corresponding exactly with the Phylogeny of the human heart (Table XLI), its Ontogeny exhibits a gradual transition from the Fish heart through the Amphibian heart to the Mammalian heart. The most important step in this advance is the formation of a longitudinal partition, imperfect at first, afterwards complete, by which all the three sections of the heart are separated into a right (venous) and a left (arterial) half. (Cf. Figs. 309–314.) The auricle (*atrium*) is thus divided into a right and a left auricle, each of which acquires its respective auricular process; the body-veins discharge into the right auricle (ascending and descending *vena cavæ*, Fig. 311, *c*, Fig. 313, *c*); the left auricle receives the lung-veins. Similarly, a superficial "interventricular furrow" (*sulcus interventricularis*, Fig. 312, *s*) appears at an early period on the main chamber of the heart, the external expression of the internal partition, by the formation of which the ventricle is divided into two chambers, a right (venous) and a left (arterial) ventricle. Finally, a longitudinal partition forms, in a similar way, in the third section of the primitive heart, which so much resembles that of a Fish, in the arterial stalk, which is also externally indicated by a longitudinal furrow (Fig. 312, *af*). This separates the cavity of the artery-stalk into two lateral halves; the main lung artery, which opens into the

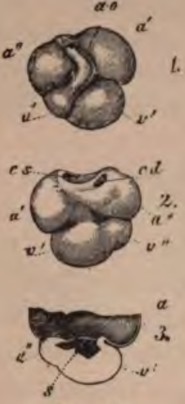


FIG. 311.

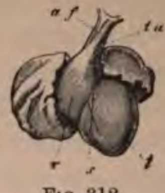


FIG. 312.

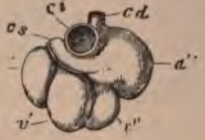


FIG. 313.

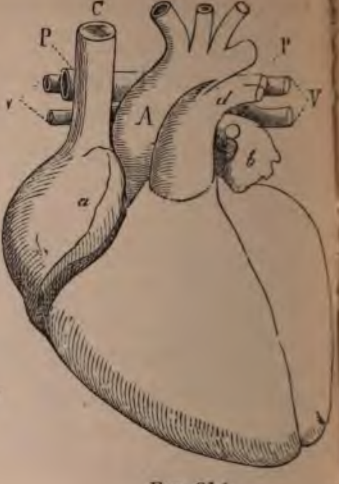


FIG. 314.

FIG. 311.—Heart of a human embryo of four weeks; 1, from the front; 2, from the back; 3, open, and with the upper half of the auricle removed; *a'*, left auricular process; *a''*, right auricular process; *v'*, left ventricle; *v''*, right ventricle; *ao*, artery-stalk; *c*, upper hollow vein (*vena cava*) (*cd*, right, *cs*, left); *s*, rudiment of the partition, between the chambers. (After Koelliker.)

FIG. 312.—Heart of a human embryo of six weeks, from the front: *r*, right ventricle; *t*, left ventricle; *s*, furrow between the two ventricles; *ta*, artery-stalk; *af*, furrow on its surface; at the right and left are the two large auricular processes of the heart. (After Ecker.)

FIG. 313.—Heart of a human embryo of eight weeks, from behind: *a'*, left auricular process; *a''*, right auricular process; *v'*, left ventricle; *v''*, right ventricle; *cd'*, right upper *vena cava*; *cs*, left upper *vena cava*; *ci*, lower *vena cava*. (After Koelliker.)

FIG. 314.—Heart of human adult, perfectly developed, from the front, in its natural position: *a*, right auricular process (below it, the right ventricle); *b*, left auricular process (below it, the left ventricle); *C*, upper *vena cava*; *V*, lung-veins; *P*, lung-artery; *d*, Botalli's duct; *A*, aorta. (After Meyer.)

right ventricle, and the aorta-trunk, which opens into the left ventricle. Not until all these partitions are complete, is the lesser, or lung-circulation, entirely distinct from the greater, or body-circulation; the right half of the heart is the centre of motion for the former, the left half for the latter. (Cf. Table XLI.)

In the human embryo, and in all other Amniota, the heart originally lies far forward on the lower side of the head, as in Fishes it remains permanently near the throat. Afterwards, with the advancing development of the neck and chest, the heart continually moves further back, until at last it is situated in the lower part of the breast between the lungs. At first its position is symmetrical, in the central plane of the body, so that its longitudinal axis corresponds with that of the body (Plate IV. Fig. 8). In most Mammals it retains this symmetrical position permanently; but in the Apes the axis begins to incline obliquely, and to move the apex of the heart to the left side. This inclination is carried furthest in the Man-like Apes; in the Chimpanzee, Gorilla, and Orang, which also resemble Man in this oblique position of the heart.

The germ-history of all other parts of the vascular system, like that of the heart, point out many and valuable facts regarding the history of our descent. But as an accurate knowledge of the complex arrangement of the entire vascular system of Man and other Vertebrates is required, in order to follow the matter sufficiently far to make it intelligible, we cannot here enter into any further detail.[192] Moreover, many important features in the Ontogeny of the vascular system, especially in regard to the derivation of its various parts from the secondary germ-layers, are as yet very obscure and doubtful. This is true, for example, of the question as to the origin of the cœlom-epithelium—that is, of the cell-layer coating the body-cavity. Probably there is an important phylogenetic distinction between the exocœlar, or the parietal cœlom-epithelium, which originates from the skin-fibrous layer, and the endocœlar, or the visceral cœlom-epithelium, which is derived from the intestinal-fibrous layer. The former is, perhaps, connected with the male germ-epithelium (the rudiment of the testes), the latter with the female germ-epithelium (the rudiment of the ovary). (Cf. Chapter XXV.)

TABLE XL.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE HUMAN VASCULAR SYSTEM.

I. *First Period: Vascular System of the earlier Scolecida.*

Between the skin-covering and the intestinal wall is formed a simple body-cavity (*cœloma*), or a perienteric cavity (as in the extant *Bryozoa* and other *Cœlomati*).

II. *Second Period: Vascular System of the more recent Scolecida.*

The first real blood-vessels form in the intestinal wall (in the intestinal-fibrous layer), a dorsal vessel in the central line of the dorsal side of the intestinal tube, and a ventral vessel in the central line of its ventral side. The two vessels are connected by several circular vessels, encircling the intestine.

III. *Third Period: Vascular System of the earlier Chordonia.*

By the modification of the anterior half of the intestine into a gill-intestine, the anterior section of the ventral vessel becomes a gill-artery, and the anterior section of the dorsal vessel a gill-vein; between the two a gill capillary network develops.

IV. *Fourth Period: Vascular System of the more recent Chordonia.*

The portion of the ventral vessel, lying immediately behind the gill-intestine, enlarges to a simple heart-pouch (Ascidian).

V. *Fifth Period : Vascular System of the Acrania.*

The ventral vessel (intestinal vein) forms, round the developing liver-sac, the first rudiment of a vena portæ system.

VI. *Sixth Period : Vascular System of the Cyclostomi.*

The single-chambered heart divides into two chambers; a posterior ventricle, and an anterior auricle. The lymph-vessel system develops side by side with the blood-vessel system.

VII. *Seventh Period : Vascular System of the Primitive Fishes, or Selachii.*

From the anterior section of the main chamber of the heart arises an artery-stalk or trunk, from which five (?) pairs of arterial arches proceed.

VIII. *Eighth Period : Vascular System of the Mud-fishes.*

From the last (fifth) pair of arterial arches the lung-arteries develop, as in the Dipneusta.

IX. *Ninth Period : Vascular System of Amphibia.*

The gill-arches gradually disappear with the gills. The right and left aortal arches remain.

X. *Tenth Period : Vascular System of Mammals.*

The separation of the greater from the lesser circulation is complete. The right aortal arch unites with Botalli's duct.

TABLE XLI.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE HUMAN HEART.

I. *First Period : Heart of Chordonia.*

The heart forms a simple spindle-shaped enlargement of the ventral vessel, with an alternating blood-current (as in Ascidia).

II. *Second Period : Heart of Acrania.*

The heart is like that of *Chordonia*, but the blood-current acquires a constant direction, passing only from back to front. (Retrograded in Amphioxus.)

III. *Third Period: Heart of Cyclostoma.*

The heart divides into two chambers, a posterior auricle (*atrium*) and an anterior ventricle (*ventriculus*).

IV. *Fourth Period: Heart of Primitive Fishes.*

From the anterior section of the ventricle is differentiated an arterial stalk (*bulbus arteriosus*), as in all Selachii.

V. *Fifth Period: Heart of the Mud-fishes.*

The auricle divides, by an imperfect and interrupted partition, into a right and a left half, as in Dipneusta.

VI. *Sixth Period: Heart of Amvhibia.*

The partition between the right and left auricles becomes complete, as in the higher Amphibia.

VII. *Seventh Period: Heart of Protamnia.*

The main chamber of the heart divides, by an incomplete partition, into a right and a left half, as in Reptiles.

VIII. *Eighth Period: Heart of Monotrema.*

The partition between the right and left ventricles becomes complete, as in all Mammals.

IX. *Ninth Period: Heart of Marsupials.*

The valves between the auricles and ventricles (atrio-ventricular valves), together with the connecting filaments and papillary muscles belonging to them, are differentiated from the muscular masses of Monotremes.

X. *Tenth Period: Heart of Apes.*

The main axis of the heart, lying in the central line of the body becomes oblique, so that the apex is turned to the left, as in Apes and Man.

TABLE XLII.

Systematic Survey of those Primitive Organs which must probably be regarded as homologous in Worms, Articulated Animals, Soft-bodied Animals, and Vertebrates.[193]

Worms (*Vermes*).	**Articulated Animals** (*Arthropoda*).	**Soft-bodied Animals** (*Mollusca*).	**Vertebrates** (*Vertebrata*).
I. *Products of the Differentiation of the Skin-sensory Layer.*			
1. Outer skin (*Epidermis*)	**1. Chitinous skin** (*Hypodermis*)	**1. Outer skin** (*Epidermis*)	**1. Outer skin** (*Epidermis*)
2. Brain (upper throat-ganglia)	**2. Brain (upper throat-ganglia)**	**2. Brain (upper throat-ganglia)**	**2. Medullary tube (anterior part)**
2. Excretory organs (water - vessels, segmental organs)	**3. Shell-glands of the Crustacean (trachea of the Tracheata ?)**	**3. Rudimentary kidneys (Primitive kidneys)**	**3. Primitive kidney-ducts (*Protureteres*) and segmental organs**
II. *Products of the Differentiation of the Skin-fibrous Layer.*			
4. Leather-skin (*Corium*) (together with the circular muscle-pouch ?)	**4. Leather-skin (Rudiment)**	**4. Leather-skin** (*Corium*) (together with the muscles of the skin ?)	**4. Leather-skin** (*Corium*) (together with the muscular layer of the skin ?)
5. Longitudinal muscle-pouch	**5. Trunk-muscles**	**5. Inner trunk-muscles**	**5. Side trunk-muscles**
6. Exocœlar innermost cell-layer of the body-wall (also male germ-plate?)	**6. Exocœlar innermost cell-layer of the body-wall (also male germ-plate?)**	**6. Exocœlar parietal epithelium of the cœlom (also male germ-plate ?)**	**6. Exocœlar parietal epithelium of the cœlom (also male germ-plate ?)**
III. *Products of the Differentiation of the Intestinal-fibrous Layer.*			
7. Body-cavity (*Cœloma*)	**7. Body-cavity** (*Cœloma*)	**7. Body-cavity** (*Cœloma*)	**7. Pleuro-peritoneal cavity**
8. Endocœlar outermost cell-layer of the intestinal wall (together with the female germ-plate ?)	**8. Endocœlar outermost cell-layer of the intestinal wall (together with the female germ-plate ?)**	**8. Endocœlar visceral epithelium of the cœlom (together with the female germ-plate ?)**	**8. Endocœlar visceral epithelium of the cœlom (together with the female germ-plate ?)**
9. Dorsal vessel	**9. Heart**	**9. Chamber of the heart (and main artery)**	**9. Aorta (primordial)**
10. Ventral vessel	**10. ——**	**10. ——**	**10. Heart (and gill-artery)**
11. Intestinal wall (except the epithelium)	**11. Intestinal wall (except the epithelium)**	**11. Intestinal wall (except the epithelium)**	**11. Intestinal wall (except the epithelium)**
IV. *Products of the Differentiation of the Intestinal-glandular Layer.*			
12. Intestinal epithelium	**12. Intestinal epithelium**	**12. Intestinal epithelium**	**12. Intestinal epithelium**

CHAPTER XXV.

DEVELOPMENT OF THE URINARY AND SEXUAL ORGANS.

Importance of Reproduction.—Growth.—Simplest Forms of Asexual Reproduction: Division and the Formation of Buds (Gemmation).—Simplest Forms of Sexual Reproduction: Amalgamation of Two Differentiated Cells; the Male Sperm-cell and the Female Egg-cell.—Fertilization.—Source of Love.—Original Hermaphroditism; Later Separation of the Sexes (Gonochorism).—Original Development of the Two Kinds of Sexual Cells from the Two Primary Germ-layers.—The Male Exoderm and Female Entoderm.—Development of the Testes and Ovaries.—Passage of the Sexual Cells into the Cœlom.—Hermaphrodite Rudiment of the Embryonic Epithelium, or Sexual Plate.—Channels of Exit, or Sexual Ducts.—Egg-duct and Seed-duct.—Development of these from the Primitive Kidney Ducts.—Excretory Organs of Worms.—"Coiled Canals" of Ringed Worms (*Annelida*).—Side Canals of the *Amphioxus.*—Primitive Kidneys of the *Myxinoides.*—Primitive Kidneys of Skulled Animals (*Craniota*).—Development of the Permanent Secondary Kidneys in *Amniota.*—Development of the Urinary Bladder from the Allantois.—Differentiation of the Primary and Secondary Primitive Kidney Ducts.—The Müllerian Duct (Egg-duct) and the Wolffian Duct (Seed-duct).—Change of Position of the Germ-glands in Mammals.—Formation of the Egg in Mammals (Graafian Follicle).—Origin of the External Sexual Organs.—Formation of the Cloaca.—Hermaphroditism in Man.

"The most important truths in Natural Science are discovered, neither by the mere analysis of philosophical ideas, nor by simple experience, but by *reflective experience*, which distinguishes the essential from the accidental in the phenomena observed, and thus finds principles from which many experiences can be derived. This is more than mere experience; it is, so to speak, philosophical experience."—JOHANNES MÜLLER (1840).

IF we judge of the importance of the organ-systems of the animal body according to the number and variety of phenomena which they present, and according to the physiological interest connected with them, we must recognize as one of the most important and interesting organic systems, the one to the development of which we now, finally, turn; the system of the reproductive organs. Just as nutrition is the first and most important condition of self-preservation of the organic individual, so by reproduction alone is the preservation of the kind or species effected, or, rather, the preservation of the long series of generations, which in their genealogical connection form the sum of the organic tribe, or phylum. No organic individual enjoys an eternal life. To each is granted but a short span of time for his individual evolution, a brief, fleeting moment in the long millions of years of the earth's organic history.

Reproduction in connection with Heredity has, therefore, long been regarded as, after nutrition, the most important fundamental function of the organism, and it is customary to make this a primary distinction between living bodies and lifeless or inorganic bodies. But this distinction is in reality not so deep and thorough as it at first appears, and as is generally assumed. For, if the nature of the phenomena of reproduction is closely considered, it is soon seen that it may be reduced to a more general quality, that of growth, which belongs to inorganic, as well as to organic bodies. Reproduction is a nutrition and a growth of the organism beyond the individual size, which, therefore, raises a part of the organism to the rank of a whole (vol. i. p. 159). This is most clearly seen by observing the reproduction of the simplest and lowest organisms, especially of the Monera (p. 46) and of the one-celled Amœba (p. 48). In these, the simple individual possesses only the form-value of a single plastid. As soon as, by continued nutrition and simple growth, this has reached a certain size, it does not exceed that size, but falls, by simple division, into two similar halves. Each of these two halves thenceforth leads an independent life, and again grows, till, having reached the same limit of growth, it once more divides. At each of these simple self-divisions, two new central points of attraction for the particles of the body are formed, as foundations of the two new individuals.[194]

In many other Primitive Animals (*Protozoa*), the simple reproduction is accomplished, not by division, but by the formation of buds (gemmation). In this case, the growth, which prepares the way for reproduction, is not total (as in the case of division), but partial. Hence in the case of gemmation, the product of local growth, which, as a bud, forms a new individual, can be distinguished, as a young individual, from the parent-organism from which it originates. The latter is older and larger than the former. In the case of division, on the contrary, the two products are of equal age and of equal form-value. Further differentiated forms of asexual reproduction, connected with gemmation, are, thirdly, the formation of germ-buds, and, fourthly, the formation of germ-cells. The latter, however, brings us directly to sexual reproduction, for which the opposed differentiation of the two sexes is the condition. In my *Generelle Morphologie* (vol. ii. pp. 32–71), and in my "Natural History of Creation" (vol. i. p. 183), I have fully discussed the connection of these various forms of reproduction.

None of the earliest ancestors of Man and of the higher animals were capable of the higher function of sexual reproduction, but multiplied only in an asexual manner, by division or gemmation, by the formation of germ-buds, or of germ-cells, as is still the case with most Primæval Animals or Protozoa. It was not until a later period in the organic history of the earth, that sexual difference of the two sexes could arise; and this took place at first in the simplest manner by the severance of two cells which amalgamated from the community of the many-celled organism. We may say that, in this case, growth, which is the condition necessary to reproduction, was attained by the union of two full-grown cells into a single cell which then exceeded its proper size ("copulation" or conjugation"). At first, the two united cells may have been entirely alike. Soon, however, by natural selection, a contrast must have arisen between them. For it must have been very advantageous to the newly-created individual in the struggle for existence, to have inherited various qualities from the two parent-cells. The complete development of this progressive contrast between the two producing cells, led to sexual differentiation. One cell became a female egg-cell, the other, a male seed or sperm cell.

The simplest form of sexual reproduction among existing animals, is exhibited in Gastræads and the lower Sponges, especially the Chalk Sponges, and, also, in the simplest

Hydroid Polyps. In the Haliphysema (Fig. **315**) and in the Olynthus the whole body is a simple intestinal pouch, which is only essentially distinguished from the gastrula by the fact that it is adherent by the end opposite the mouth. The thin wall of the pouch consists only of the two primary germ-layers. As soon as it is sexually mature, single cells of the wall become female egg-cells, others become male sperm-cells, or seed-cells; the former grow very large, as they form a considerable number of yelk-granules in their protoplasm (Fig. 181, *e*); the latter, on the contrary, by continued division, become very small, and modify into movable "pin-shaped" spermatozoa (Fig. **17**, vol. i. p. 173). Both kinds of cells sever themselves from their birthplace, the primary germ-layers, fall either into the surrounding water or into the intestinal cavity, and there unite by amalgamation. This is the very important process of the fertilization of the egg-cell by the sperm-cell. (Cf. Fig. **18**, vol. i. p. 175.)

These simplest processes of sexual reproduction, as exhibited at the present time in the lowest Plant Animals, especially in the Chalk Sponges and Hydroid Polyps, inform us of several extremely important and significant facts; in the first place, we learn, that for sexual reproduction in its simplest form, nothing more is required than the blending or amalgamation of two differing cells, a female egg-cell and a male sperm-cell, or seed-cell. All other circumstances, and all the other extremely complex phenomena, accompanying the act of sexual reproduction in the higher animals, are of a subordinate and secondary character, and have only attached themselves secondarily to that simplest primary process of copulation or fertilization, or have arisen by differentiation. But, now, if we consider what an extraordinarily important part is everywhere played by the relation of the two sexes in organic nature, in the vegetable kingdom, as in animal and human life; how the reciprocal inclination and attraction of the sexes, love, gives the impetus of the most varied and remarkable processes, is, even, one of the most important mechanical causes of the highest differentiation in life;—if we consider this, we cannot over-estimate this retracing of "love" to its primitive source, to the power of attraction between two differing cells. Everywhere throughout animated nature the greatest results proceed from this most insignificant cause. It is only necessary to think of the part played in nature by the flowers, the reproductive organ of flowering plants; or of the multitude of wonderful phenomena caused by sexual selection in animal life; or, finally, of the important influence exerted by love on human life: the coalescence of two cells is everywhere the single, original impelling motive; everywhere this apparently trivial pro-

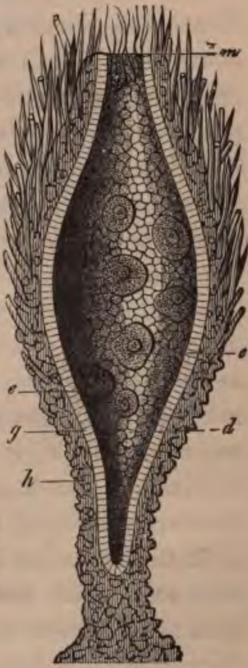


FIG. 315.—Longitudinal section through a Haliphysema (*Gastræada*) The egg-cells (e) are enlarged epithelial cells of the entoderm (g), and lie freely in the primitive intestinal cavity (d): m, mouth-opening; h, exoderm.

cess exerts the greatest influence on the development of the most varied circumstances. We may, indeed, assert, that no other organic process can be, even remotely, compared to this in extent and intensity of differentiating effect. For is not the Semitic myth of Eve, who seduced Adam to knowledge, and is not the old Greek legend of Paris and Helen, and are not very many other famous fictions, merely the poetical expression of the immeasurable influence, which love, in connection with "sexual selection,"[36] has exerted, ever since the differentiation of the two sexes, on the progress of the world's history? All other passions that agitate the human breast are in their combined effects far less powerful than love, which inflames the senses and fools the understanding. On the one hand, we gratefully glorify love as the source of the most splendid creations of art; of the noblest productions of poetry, of plastic art and of music; we reverence in it the most powerful factor in human civilization, the basis of family life, and, consequently, of the development of the state. On the other hand, we fear in it the devouring flame which drives the unfortunate to ruin, and which has caused more misery, vice, and crime, than all the other evils of the human race taken together. So wonderful is love, and so immeasurably important is its influence on mental life, on the most varied functions of the medullary tube, that in this point, more than in any other, "supernatural" causation seems to mock every natural explanation. And yet, notwithstanding all this, the comparative history of evolution leads us back very clearly and indubitably to the oldest and simplest source of love, to the elective affinity of two differing cells: the sperm-cell and the egg-cell.

Just as the lowest Plant Animals exhibit this most simple origin of the complex phenomena of reproduction, so, in the second place, they reveal the highly important fact, that the earliest and most primitive sexual relation was hermaphroditism, and that the separation of the sexes originated from this only secondarily (by division of labour). Hermaphroditism is prevalent in lower animals of the most different groups; in these, each single individual, when sexually mature, each person, contains male and female sexual cells, and is, therefore, capable of self-fertilization and self-reproduction. Thus, not only in the lowest Plant Animals just mentioned (the Gastræads, Chalk-sponges, and many Hydroid Polyps) do we find egg-cells and sperm-cells united in one and the same person; but many Worms (for example, the Ascidians, Earth Worms and Leeches), many Snails (the common garden Snail), and many other invertebrate animals are also hermaphrodite. All the earlier invertebrate ancestors of man, from the Gastræada up to the Chordonia, must also have been hermaphrodite. So, probably, were also the earliest Skulled Animals (Figs. 52–56, *e*, *h*, vol. i. p. 256). One extremely weighty piece of evidence of this is afforded by the remarkable fact, that even in Vertebrates, in Man as well as other Vertebrates, the original rudiment of the sexual organs is hermaphrodite. The separation of the sexes (*Gonochorism*), the assignment of the two kinds of sexual cells to different individuals, originated from hermaphroditism only in the farther course of tribal history. At first, male and female individuals differed only in the possession of the two kinds of cells, but in other respects were exactly alike, as is now the case in the Amphioxus and the Cyclostoma.

Not until a later period, by the law of sexual selection, so brilliantly elucidated by Darwin, were developed the so-called "secondary sexual characters," that is, those differences in the male and female sexes which are exhibited, not in the sexual organs themselves, but in other parts of the body (for example, the beard of the man, the breast of the woman).[36]

The third important fact, taught us by the lower Plant Animals, refers to the earliest origin of the two kinds of sexual cells. For, as in Gastræads, and in many Sponges and Hydroids, in which we meet with the simplest rudiments of sexual differentiation, the whole body consists throughout life only of the two primary germ-layers, the two kinds of sexual cells can, therefore, only have originated from cells of the two primary germ-layers. This simple discovery is of extreme importance, because the question of the first origin of the egg-cells as well as of the sperm-cells in the higher animals—and especially in Vertebrates—presents unusual difficulties. In these animals it usually appears as if the sexual cells developed, not from one of the two primary, but from one of the four secondary germ-layers. If, as most authors assume, they do originate from the middle-layer, or mesoderm, the fact is due to an ontogenetic heterotopism, to a displacement in position. (Cf. vol. i. p. 13.) Unless the unjustifiable and paradoxical assumption, that the sexual cells are of entirely different origin in the higher and in the lower animals, is accepted, we are compelled to derive them originally (phylogenetically), in the former as in the latter, from one of the two primary germ-layers. It must then be assumed that these cells of the skin-layer or of the intestinal layer, which must be regarded as the earliest progenitors of the sperm-cells and of the egg-cells, withdrew, during the separation of the skin-fibrous layer from the skin-sensory layer, or of the intestinal-fibrous layer from the intestinal-glandular layer, into the body-cavity *cœloma*), which was in process of formation; and that they thus acquired the internal position between the two fibrous layers, which appears as their original position, when the sexual cells first become distinct in the vertebrate embryo. Otherwise, we should be obliged to accept the improbable polyphyletic hypothesis, that the origin of the egg-cells and sperm-cells is different in the higher and in the lower animals, that their origin in the former is independent of that in the latter.

If we, accordingly, derive the two kinds of sexual cells from the two primary germ-layers in man as in all other animals, the farther question arises: Did the female egg-cells and the male sperm-cells develop from both primary germ-layers, or from one only? and, in the latter case, from which of the two? This important and interesting question is one of the most difficult and obscure problems in the history of evolution, and, up to the present moment, no full and clear solution has been attained. On the contrary, the most opposite answers are given to it even yet by naturalists of note. Among the various possible solutions only two have been generally considered. It has been supposed that both kinds of sexual cells originally developed from the same primary germ-layer, either from the skin-layer or the intestinal layer; but almost as many and as able observers have accepted the one as the origin as the other. Quite recently the Belgian naturalist, Eduard van Beneden, has asserted, on the contrary, that the egg-cells originate from the intestinal layer, the sperm-cells from the skin-layer.[195] In Gastræads, Sponges, and Hydro-medusæ this appears really to be the case. The development of the sexual differences, which is so rich in results, must, accordingly, have commenced even during the differentiation of the two primary germ-layers in the simplest and lowest Plant Animals; the exoderm would be the male germ-layer, the entoderm, the female. If this discovery of Van Beneden is established and proves to be a universal law, Biology will gain a most pregnant advance; for not only would all the contradictory empiric explanations be answered, but a new path would be opened for philosophic reflection on one of the most important of biogenetic processes.

If we now trace the Phylogeny of the sexual organs in our earliest Metazoic ancestors further, as it is indicated, at the present time, in the Comparative Anatomy and Ontogeny of the lowest Worms and Plant Animals, we note, as the first advance, the accumulation of the cells of both sexes into definite groups. While in Sponges and the lowest Hydra-Polyps single scattered cells separate from the cell-layers of the two primary germ-layers, and become isolated and free sexual cells, in the higher Plant Animals and Worms we find these same cells associated and collected into groups of aggregate cells, which are, henceforward, called "sexual glands," or "germ-glands" (*gonades*). It is only now that we can speak of sexual organs in the morphological sense. The female germ-glands which, as such, in their simplest form constitute a mass of homogenous egg-cells, are the ovaries (*ovaria*, or *oophora*; Fig. 211, *e*, p. 198). The male germ-glands, which in their primitive form also consist merely of a mass of sperm-cells, are the testes (*testiculi*, or *orchides;* Fig. 211, *h*). We find the ovaries and testes in this earliest and simplest shape not only in many Worms (*Annelida*) and Plant Animals, but also in the lowest Vertebrates, in the Skull-less Animals (*Acrania*). In the anatomy of the Amphioxus we found the ovaries of the female and the testes of the male consisting of twenty to thirty elliptic or roundly four-cornered simple sacs, of small size, attached to the inside of the gill-cavity on each side of the intestine. (Cf. vol. i. p. 425.)

Only a single pair of germ-glands, lying far down in the floor of the body-cavity (Fig. 316, *g*), exist in all Skulled Animals (*Craniota*). The first traces of these appear in the cœlom-epithelium. Probably, in this case also, the male sperm-cells originate from the skin-layer, the female egg-cells, on the contrary, from the intestinal layer. The earliest traces are visible in the embryo at the point where the skin-fibrous layer and the intestinal-fibrous layer meet in the middle plate (mesentery-plate) (Fig. 318, *mp*, p. 408). At this very important point in the cœlom-wall, where the endocœlar (or visceral cœlom-epithelium) merges into the exocœlar (or parietal cœlom-epithelium), in the embryo of Man and the other Skulled Animals a small aggregation of cells becomes visible, at a very early period, and this, according to Waldeyer,[196] we may call the "germ-epithelium," or (corresponding with the other plate-shaped rudiments of organs) the sexual plate (Fig. 316, *g*; Plate IV. Fig. 5, *k*). The cells of this germ-plate, or sexual plate (*lamella sexualis*) are essentially distinguished by their cylindrical form and by their chemical constitution from the other cells of the cœlom; they are of quite different significance from the flat cells of the "serous cœlom-epithelium" which line the remainder of the body-cavity (*cœloma*). Of these latter—the true cœlom-cells—those which invest the intestinal tube and the mesentery ("*endocœlar*") originate from the

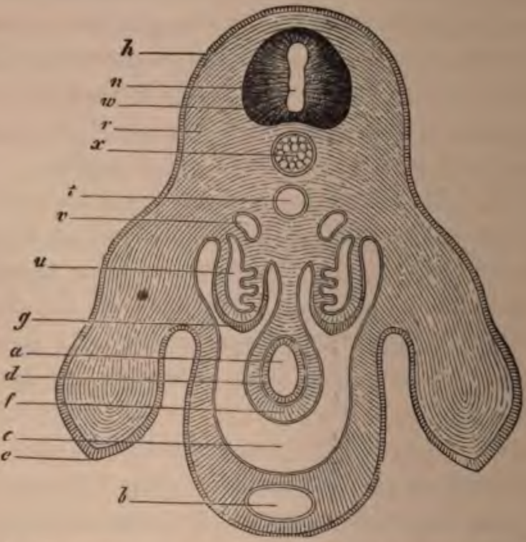


FIG. 316.—Transverse section through the pelvic region and the hind limbs of an embryo Chick in the fourth day of incubation, enlarged about 40 times: *h*, horn-plate; *w*, medullary tube; *n*, canal of the medullary tube; *u*, primitive kidneys; *x*, notochord; *e*, hind limbs; *b*, allantois canal in ventral wall; *t*, aorta; *v*, cardinal veins; *a*, intestine; *d*, intestinal-glandular layer; *f*, intestinal-fibrous layer; *g*, germ-epithelium; *r*, dorsal muscles; *c*, body-cavity, or Cœlom. (After Waldeyer.)

intestinal-fibrous layer (in Fig. 5, Plate IV., coloured red); those which line the inner surface of the external wall of the abdomen ("*exocœlar*") are, on the contrary, the product of the skin-fibrous layer (coloured blue in Fig. 5, Plate IV.); but the sexual cells which make their appearance at the boundary line between the two forms of cœlom-cells, and which insert themselves, to a certain extent, between the endocœlar and the exocœlar, there forming the germ-plate, cannot be referred either to the intestinal-fibrous layer or to the skin-fibrous layer, but directly to the two primary germ-layers; for there are important grounds for supposing that even the first rudiment of the sexual plate is, probably, hermaphroditic, and that this "sexual epithelium" (visible, in Man and all other Vertebrates, between the exocœlar and the endocœlar) represents a primæval and simple hermaphrodite gland. (Cf. vol. i. p. 256, Figs. 52–56, *e*, *h*.) The inner half of this, in contact with the intestinal-fibrous layer, which is derived from the intestinal-glandular layer, would be the rudiment of the ovary; its outer half, in contact with the skin-fibrous layer, which originates from the intestinal-glandular layer, would be the rudiment of the testes. This is, of course, only conjectural.

We ought, accordingly, to distinguish two different sexual plates or germ-epithelia; the female sexual plate, a product of the intestinal layer, which gives rise to the ovary-epithelium—the mother cells of the ova ("ovary-plate"); and the male sexual plate, lying externally over the former, and which is a product of the skin-layer, from which originates the testes-epithelium—the mother cells of the sperm-threads ("testes-plate"); but even the first recognizable rudiments of the two sexual plates appear, indeed, so intimately associated in the human embryo and in those of the higher Vertebrates, that hitherto they have been regarded as a single, undifferentiated, common rudiment of an organ; and it is still possible that the two kinds of sexual glands arise by secondary differentiation from a common rudiment.

Though we must recognize the formation of the two kinds of sexual cells, and in their union at fertilization as the one essential act of sexual reproduction, yet, in the great majority of animals, other organs exist which also take part in the act of fertilization. The most important of these secondary sexual organs are the exit-ducts which serve to conduct the mature sexual cells out of the body, and, next to these, the copulative organs, which transmit the fertilizing sperm from the male person to the female, in which the eggs are situated. These latter organs exist only in the higher animals of various tribes, and are far less widely distributed than the exit-ducts. Even these latter, however, are only of secondary formation, and are wanting in many animals of the lower groups. In these, as a rule, the mature sexual cells are simply ejected from the body. In some cases they pass out directly through the outer skin-covering (as in the Hydra and many of the Hydroidea); in other cases, they enter the stomach-cavity, and are ejected through the mouth-opening (in Gastræads, Sponges, and other Hydroid Polypes and Coral Animals); in yet other cases, they enter the body-cavity and pass out through a special aperture in the ventral wall (*porus genitalis*). The latter is the case in many Worms and even in a few lower Vertebrates (Cyclostoma and a few Fishes). These indicate the earliest condition of this matter as it was in our ancestors. On the other hand, in all higher, and most lower Vertebrates (as also in most higher Invertebrates) special tube-shaped exit-ducts from the sexual cells, or sexual ducts (*gonophori*), are present in both sexes. In the female these convey the egg-cells out from the ovaries, and hence they have been called egg-ducts (*oviductus*, or *tubæ fallopiæ*). In the male sex these tubes convey the sperm-cells from the testes, and hence they are called sperm-ducts (*spermaductus*, or *vasa deferentia*).

The original, genetic condition of these two outlets is exactly the same in Man as in all higher Vertebrates, while in most Invertebrates it is entirely different; for while in the latter the sexual ducts develop directly from the sexual glands, or from the external skin, or from the intestinal canal, in Vertebrates an organ-system is employed for the conveyance of the sexual products; one which originally had a very different significance and function—the kidney system, or urinary organs. The original, primary function of these organs is simply to eliminate useless matter from the body in a liquid form. The liquid product of this secretion is called the urine, and is discharged either directly through the external skin, or through the last section of the intestine. The tube-shaped "urinary ducts" only secondarily absorb the sexual products also and convey them out; they thus become "urogenital ducts" (*ductus urogenitales*). This remarkable secondary combination of the urinary and the sexual organs into a common "urogenital apparatus," or "urogenital system," is highly characteristic of the higher Vertebrates. In the lowest of these it is, however, wanting, while, on the other hand, it is found in the higher Ringed Worms (*Annelida*). To estimate this rightly, we must first glance at the comparative economy of the urinary organs as a whole.

The kidney system or urinary system (*systema uropoeticum*) is one of the earliest and most important organ-systems in the differentiated animal body, as has already been incidentally mentioned. (Cf. Chapter XVII.) It is found almost universally distributed, not only in the higher animal tribes, but even in the more primitive Worm tribe. Among the latter it even occurs in the lowest and most imperfect known Worms—the Flat Worms (*Plathelminthes*) (Fig. 184, *nc*, p. 80). Although these accœlomatous Worms have no body-cavity, no blood, no vascular system, they always have a kidney system. It consists of a pair of simple or of branched canals, lined by a layer of cells, which absorb useless juices from the tissues and discharge them through an external skin-opening (Fig. 184, *nm*). Not only the free-living Gliding Worms (*Turbellaria*), but also the parasitic Sucking Worms (*Trematoda*), and even the still more degraded Tape Worms, which, in consequence of their parasitic habit of life, have lost their intestinal canal, are all provided with these "kidney canals" or primitive kidneys. Usually these canals in the Worms are called excretory organs, and in former times they used to be called water-vessels. Phylogenetically they must be regarded as highly-developed pouch-like skin-glands resembling the sweat-glands of Mammals, and, like these, developed from the skin-sensory layer. (Cf. Fig. 210, *n*, p. 198, and Fig. 214, p. 202.)

While in these lowest unsegmented Worms only a single pair of kidney ducts is present, in the higher segmented Worms these ducts exist in greater numbers. In Ringed Worms (*Annelida*), in which the body is composed of a great number of segments, or metamera, a pair of these primitive kidneys (hence known as segmental organs, or canals) exists in each separate segment. In this case, also, the canals are very simple tubes, which, on account of their coiled or looped form, are called "coiled canals." To the primary, external aperture in the outer skin, originally alone present, a secondary, internal aperture into the body-cavity (*cœloma*) is now added. This opening is provided with vibratory cilia, and is thus enabled to absorb the secretional juices from the body-cavity and to discharge them from the body. Now in these Worms also the sexual cells, which develop in the simplest form upon the inner surface of the abdominal wall, pass, when mature, into the cœlom, are drawn into the internal, funnel-shaped ciliated openings of the kidney canals, and are carried out of the body with the urine. Thus the urine-forming "coiled canals," or "primitive kidneys," serve, in the female Ringed Worms, as "oviducts," and, in the male, as "sperm-ducts."

It would of course be most interesting to know the condition, on this point, of the Amphioxus, which, standing midway between Worms and Vertebrates, affords us so much valuable information. Unfortunately this animal, for the present, affords no solution of this matter. At present we know nothing certainly as to the relation between the urinary and the sexual organs of the Amphioxus. Some zoologists assert that this animal has no kidneys; others regard the two long "side canals" as atrophied primitive kidney ducts (Fig. 152, *S*, vol. i. p. 423); yet others consider certain glandular epidermis-swellings on the inner surface of the gill-cavity to be rudimentary kidneys. Most probably, a great reversion has affected the original primitive kidney canals in the Amphioxus, amounting perhaps to their entire phylogenetic loss.

Very interesting inferences may be drawn from the Vertebrates of the next stage—the Monorhina, or Cyclostoma. Although both orders of this class—the Myxinoides as well as the Petromyzontes—possess developed, urine-secreting kidneys, these organs do not in this case serve to carry away the sexual cells. These cells pass directly from the germ-glands into the cœlom, and are discharged through a posterior aperture in the abdomen. The condition of the primitive kidneys in these is, however, very interesting, and throws light on the complex kidney structure of the higher Vertebrates. In the first place, in the Myxinoides (*Bdellostoma*) we find a long tube, the primitive kidney duct (*protureter*, Fig. 317, *a*), on each side. This opens internally into the cœlom through a ciliated funnel-shaped aperture (as in Ringed Worms); it opens externally through an opening in the outer skin. A great number of small horizontal tubes ("segmental canals," or primitive urine tubes) open on its inner side. Each of these terminates in a blind, vesicular capsule (*c*) enclosing a

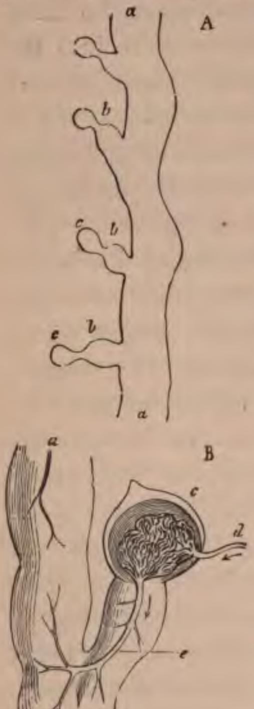


FIG. 317.—*A.* Portion of kidney of Bdellostoma: *a*, primitive kidney duct (*protureter*); *b*, segmental canals, or primitive urine canals (*tubuli uriniferi*); *c*, kidney-vesicles (*capsulæ Malphigianæ*).—*B.* Portion of the same, much enlarged: *c*, kidney-vesicle, with the *glomerulus*; *d*, approaching artery; *e*, retreating artery. (After Johannes Müller.)

knot of blood-vessels (*glomerulus*, an arterial net, Fig. 317, *B*, *c*). Afferent arterial branches (*vasa afferentia*) convey arterial blood into the coiled branches of the "*glomerulus*" (*d*), and efferent arterial branches (*vasa efferentia*) again carry it out of the *glomerulus* (*e*).

In Primitive Fishes (*Selachii*) also there is a longitudinal series of segmental canals, which open outwardly in the primitive kidney ducts. The segmental canals (a pair in each metameron of the central part of the body) open, in this case, freely into the body-cavity, through a ciliated funnel (as in Ringed Worms, or Annelids). A part of this organ forms a compact primitive kidney, while the rest is employed in the formation of the sexual organs.

The primitive kidney in the embryo of Man and in that of all other Skulled Animals (*Craniota*) is first formed in the same simple shape which persists throughout life in Myxinoides, and partly in Selachii. We found this primitive organ in the human embryo at that early period just succeeding the separation in the skin-sensory layer, of the medullary tube from the horn-plate, and the differentiation, in the skin-fibrous layer, of the notochord, the primitive vertebral plate, and the skin-muscle plate. As the first rudiment of the primordial kidneys, a long thin, thread-like string of cells, which is soon hollowed out into a canal, appears in this case, on each side, immediately below the horn-plate; this extends in a straight line from front to back, and is plainly seen in the cross section of the embryo (Fig. 318) in its original position in the space between the horn-plate (*h*), the primitive vertebræ (*uw*), and the skin-muscle plate (*hpl*). The first origin of this primitive kidney duct is still a matter of dispute, some ontogenists referring it to the horn-plate, others to the primitive vertebral plate, and yet others to the skin-muscle plate. Probably its earliest (phylogenetic) origin is to be found in the skin-sensory layer; but it very soon quits its superficial position, passes inward, between the primitive vertebral plates and the side plates, and finally lies upon the inner surface of the body-cavity. (Cf. Figs. 66–69, *u*, vol. i. p. 277, and Figs. 95–98, p. 319; also Plate IV. Figs. 3–6, *u*.) While the primitive kidney duct is thus making its way inward, on its inner and under side appear a large number of small horizontal tubes (Fig. 319, *a*), exactly corresponding to the segmental canals of the Myxinoides (Fig. 317, *b*). Like the latter, these are, probably, originally protuberances of the primitive kidney ducts (Fig. 316, *u*). At the blind, inner end of each of the primitive urinary tubes an arterial glomerulus is formed, which grows into this blind end from within, forming a "vascular coil." The glomerulus to a certain extent expands the bladder-like blind end of the small urinary tubes. As the primitive urinary tubes,

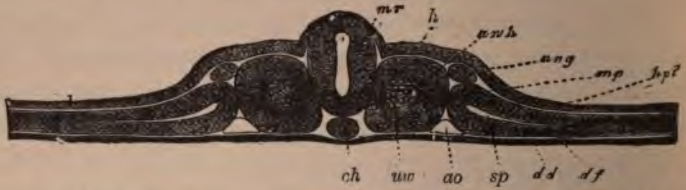
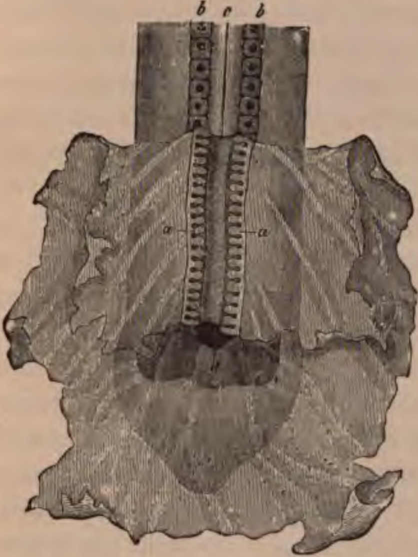


FIG. 318.—Transverse section through the embryo of a Chick, on the second day of incubation: *h*, horn-plate; *m*, medullary tube; *ung*, primitive kidney duct; *ch*, notochord; *uw*, primitive vertebral cord; *hpl*, skin-fibrous layer; *df*, intestinal-fibrous layer; *mp*, mesentery-plate, or middle plate (point of attachment of the two fibrous layers); *sp*, body-cavity (*cœloma*); *ao*, primitive aorta; *dd*, intestinal-glandular layer. (After Kölliker.)

which are, at first, very short, grow longer and broader, each of the two primitive kidneys assumes the form of a semi-pinnate leaf (Fig. 320). The urinary tubes (*u*) represent the tissue and the primitive kidney duct (*w*) the mid-rib. On the inner margin of the primitive kidney the rudiment of the hermaphrodite sexual gland already



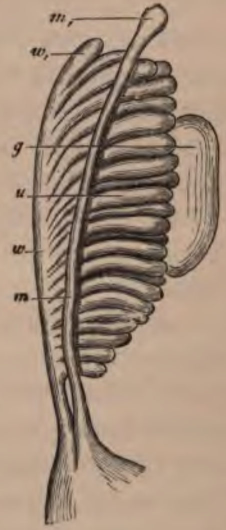


FIG. 319.—Rudimentary primitive kidney of embryonic Dog. The posterior portion of the body of the embryo is seen from the ventral side, covered by the intestinal layer of the yelk-sac, which has been torn away, and thrown back in front in order to show the primitive kidney ducts with the primitive kidney tubes (*a*) : *b*, primitive vertebræ; *c*, dorsal medulla; *d*, passage into the pelvic intestinal cavity. (After Bischoff.)

FIG. 320.—Primitive kidney of a human embryo: *u*, the urine-tubes of the primitive kidney; *w*, Wolffian duct; *w'*, upper end of the latter (Morgagni's hydatid); *m*, Müllerian duct; *m'*, upper end of the latter (Fallopian hydatid); *g*, hermaphrodite gland. (After Kobelt.)

appears as a body of considerable size. The posterior end of the primitive kidney duct opens into the lower extremity of the last section of the rectum, so that this organ becomes a cloaca. But this opening of the primitive kidney duct into the intestinal canal must be regarded, phylogenetically, as a secondary condition. Originally, as is indicated clearly in the Cyclostoma, they issued through the external abdominal skin, quite independently of the intestinal canal, thus proving their early phylogenetic origin from the horn-plate, as outer skin glands.

While in the Myxinoides the primitive kidneys permanently retain this simple form, as they do partially in Primitive Fishes (*Selachii*), in all other Craniota it appears only temporally in the embryo, as the ontogenetic reproduction of the primordial phylogenetic condition. In these Skulled Animals the primitive kidney, by vigorous growth, increases in length, and by the increase in number and the coiling of the urinary tubes, very soon assumes the form of a large compact gland, of oblong, oval, or spindle-shaped form, which extends longitudinally through the greater part of the body-cavity (*cœloma*) of the embryo (Figs. 123, *m*, 124, *m*, vol. i. p. 370). In this case, it lies near the middle line, directly under the primitive vertebral column, and extends from the region of the heart to the cloaca. The right and left primitive kidneys lie parallel and close together,, being separated only by the mesentery, that narrow, thin lamella which connects the central intestine with the lower surface of the primitive vertebral column. The excretory duct of each primitive kidney, the protureter, traverses the lower and outer side of the gland in a posterior direction, and opens into the cloaca, close to the root of the allantois ; at a later period, it opens into the allantois itself (Fig. 136, *o*, vol. i. p. 381).

The primitive kidney (primordial kidney) in the embryo of Amniota was formerly called the "Wolffian body," also the "Okenian body." In all cases it acts for a time as a true kidney, draining and secreting the useless fluids of the embryonic body, and discharging them into the cloaca and then into the allantois. The "primitive urine" collects in the latter organ, and hence the allantois in the embryo of man and of the other Amniota acts as a real urinary bladder, or "primitive urinary sac;" yet it is in no way genetically connected with the primitive kidneys, but is rather, as we have already seen, a pouch-like protuberance of the anterior wall of the terminal intestine (Fig. 135, *u*, vol. i. p. 380), The allantois is, therefore, a product of the intestinal layer, while the primitive kidneys are a product of the skin-layer. Phylogenetically we must conceive that the allantois originated as a pouch-shaped protuberance of the cloacal wall resulting from the distension caused by the collection in the cloaca of the primitive urine secreted by the primordial kidneys. It is, originally, a blind sac belonging to the rectum (Plate V. Fig. 15, *hb*). The true urinary bladder of Vertebrates, evidently, first appeared in Dipneusta (in the Lepidosiren), and was thence transmitted, first to the Amphibia, and then to the Amniota. In the embryo of the latter it protrudes far out of the yet unclosed abdominal wall. Many Fishes, indeed, also possess a so-called urinary bladder. But this is merely a local distension in the lower section of the primitive kidney ducts. and hence, both in origin and in constitution, is essentially distinct from the true urinary bladder. The two structures are only physiologically comparable; they are, therefore, analogous, as having the same function; morphologically, however, they are not to be compared, or are not homologous.[188] The false urinary bladder in Fishes is a product of the primitive kidney duct, therefore of the skin layer; the true urinary bladder in Dipneusta, Amphibia, and Amniota is, on the contrary, a blind-sac of the terminal intestine, and hence a product of the intestinal layer.

In all low Skulled Animals (*Craniota*), without amnion (in Cyclostoma, Fishes, Dipneusta, and Amphibia), the urinary organs remain in an inferior stage of development, in so far as the primitive kidneys (*protonephra*), though much modified, here act permanently as urine-secreting glands. In the three higher vertebrate classes, included in the term Amnion Animals, on the contrary, this is the case only for a short period during early embryonic life. The permanent, or secondary kidneys (*renes*, or *metanephra*), which are peculiar to these three classes, are very early developed. These originate, not (as was long believed, on the authority of Remak) as entirely new, independent glands of the intestinal tube, but from the posterior section of the primitive kidney duct (*proturetcr*). From the latter, near where it opens into the cloaca, a simple pouch—the secondary kidney duct--grows out, and this increases considerably in length forwards; from the blind, upper, or anterior portion of this the permanent kidney originates, precisely as the primitive kidney originates from the primitive kidney duct. The secondary kidney duct gives rise to a number of small blind tubes—the secondary urinary tubes — and the blind capsule-shaped ends of these are occupied by vascular coils (*glomeruli*). The further growth of these tubes results in the compact secondary kidney, which, in Man and most higher Mammals, acquires the well-known bean-like form; in the lower Mammalia, in Birds and in Reptiles, on the other hand, it is separated into several lobes. The lower, or posterior part of the permanent kidney duct retains the form of a simple canal, widens, and thus forms the permanent urine duct (*ureter*). At first this canal, yet united with the last section of the primitive kidney duct, discharges into the cloaca; at a later period, it separates from the primitive kidney duct, and yet later from the rectum, and then it discharges into the permanent urinary bladder (*vesica urinaria*). The latter originates from the posterior, or lower part of the stalk of the allantois (*urachus*), which widens and becomes spindle-shaped before opening into the cloaca. The anterior, or upper part of the allantois-stalk, which passes in the abdominal wall of the embryo to the navel, afterwards disappears, a useless cord-shaped remnant alone remaining as a rudimentary organ: this is the single urinary-bladder navel-cord (*ligamentum vesico-umbilicale medium*). On the right and left of this, in the adult Man, there are two other rudimentary organs: the lateral urinary-bladder navel-cords (*ligamenta vesico-umbilicalia lateralia*). These are the obsolete cord-like remnant of the former navel-arteries (*arteriæ umbilicales*, vol. i. p. 400; Fig. 326, *a*).

Although in Man, as in all other Amnion Animals, the primitive kidneys are thus very early displaced by the secondary kidneys, and although the latter alone afterwards act as urinary organs, the former are not, however, altogether discarded. Indeed, the primitive kidney ducts acquire a high physiological significance, as they modify into excretory ducts of the sexual glands. In all Amphirhina or Gnathostomi—therefore in all Vertebrates from Fishes up to Man—at a very early period, a second similar canal appears in the embryo at the side of each primitive kidney duct. This canal is commonly called, after its discoverer, Johannes Müller, "Müller's duct" (*ductus Mülleri*), while the earlier, primitive kidney duct is distinguished as the "Wolffian duct" (*ductus Wolffii*). The actual origin of Müller's duct is still undetermined; Comparative Anatomy and Ontogeny seem, however, to indicate that it proceeds by differentiation from the Wolffian duct. It is, probably, most correct to say, that the original (primary) primitive kidney duct breaks up by differentiation (or fission) into two secondary, similar ducts; these are the Wolffian and

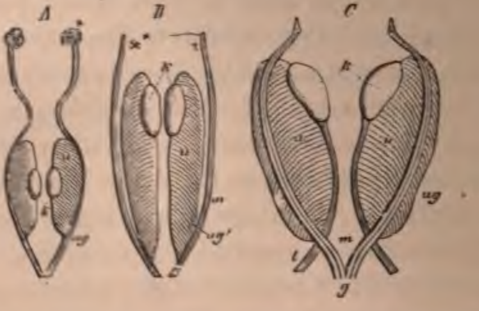
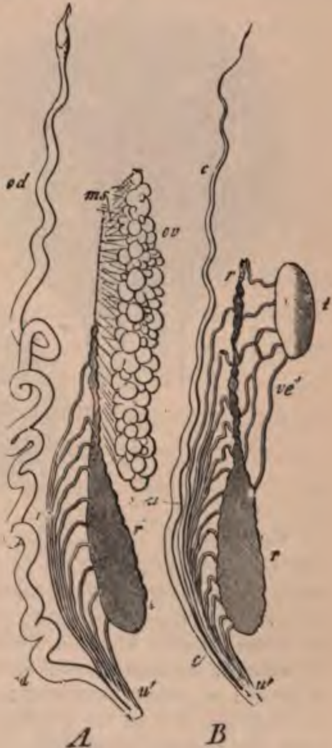


FIG. 321.—Primitive kidneys and rudiments of the sexual organs. *A* and *B*, of Amphibia (Frog larvæ); *A*, earlier, *B*, later condition. *C*, of a Mammal (embryo of Ox): *u*, primitive kidneys; *k*, sexual glands (rudiments of testes and ovaries). The primary primitive kidney duct (*ug* in Fig. *A*) separates (in *B* and *C*) into the two secondary primitive kidney ducts; the Müllerian duct (*m*) and the Wolffian duct (*ug'*), which unite behind into a genital cord (*g*); *l*, groin-cord of the primitive kidneys. (After Gegenbaur.)

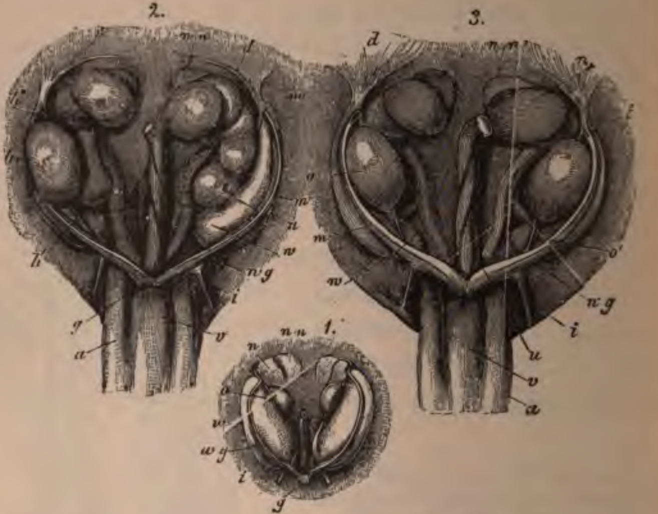
the Müllerian ducts. The latter (Fig. 320, *w*) lies immediately inside the former (Fig. 320 *m*). Both open posteriorly into the cloaca.

Obscure and uncertain as is the origin of the Müllerian and Wolffian ducts, their later history is clear and definite. In all Double-nostrilled (*Amphirhina*) and Jaw-mouthed (*Gnathostomi*) animals, from Primitive Fishes up to Man, the Wolffian duct becomes the seed-duct, and the Müllerian duct, the oviduct. In each sex only one of these is persistent; the other entirely disappears, or leaves only a remnant as a rudimentary organ. In the male sex, in which the two Wolffian ducts become sperm-ducts, certain rudiments of the Müllerian duct are often found, which we will call "Rathke's canals" (Fig. 323, *c*). In the female sex, where, on the contrary, the two Müllerian ducts



FIGS. 322, 323.—Urinary and sexual organs of an Amphibian (Water-Newt, or *Triton*). Fig. 322 (*A*), female; Fig. 323 (*B*), male: *r*, primitive kidney; *ov*, ovary; *od*, egg-duct and Rathke's duct, both formed from the Müllerian duct; *u*, primitive urinary duct—acting, in man, also as seed-duct (*ve*)—opening below into Wolff's duct (*u'*); *ms*, ovary-mesentery (*mesovarium*). (After Gegenbaur.)

become oviducts, traces of the Wolffian ducts remain, and are known as "Gartner's canals."



FIGS. 324-326.—Urinary and sexual organs of an embryonic Ox. Fig. 324, of female embryo of 1½ inch in length; Fig. 325, of male embryo of 2⅓ inches in length; Fig. 326, of female embryo of 2⅓ inches in length: *w*, primitive kidney; *wg*, Wolff's duct; *m*, Müller's duct; *m'*, upper end of the latter (opened at *t*); *i*, lower thickened end of the same (rudiment of uterus); *g*, genital cord; *h*, testes (*h'*, lower, *h''*, upper testis-cord); *o*, ovary; *o'*, lower ovary-cord; *i*, groin-cord of the primitive kidney; *d*, diaphragm-cord of the primitive kidney; *n*, permanent kidneys (below these the S-shaped urine-duct; between the two the rectum); *v*, urine-bladder; *a*, navel-artery. (After Kölliker.)

The most interesting facts in reference to this remarkable development of the primitive kidney ducts and their union with the sexual glands are exhibited in Amphibia (Figs. 321–323). The first rudiment of the primitive kidney ducts and their differentiation into the Müllerian and

Wolffian ducts is identical in both sexes, as is the case in the embryos of Mammals (Fig. 321, *C*, Fig. 324). In the female Amphibia the Müllerian duct on each side develops into a large ovary (Fig. 322, *od*), while the Wolffian duct acts permanently as a urinary duct (*u*). In the male, on the contrary, the Müllerian duct persists only as a rudimentary organ, without functional significance, as Rathke's canal (Fig. 323, *c*); the Wolffian duct serves, in this case also, as a urinary duct, but also as a sperm or seed duct, the seminal tubes (*ve*) from the testes (*t*) entering the upper part of the primitive kidneys, and there uniting with the urinary canals.

In Mammals these conditions, persistent in Amphibia, are rapidly traversed by the embryo in an early period of its development (Fig. 321, *C*). The primitive kidneys, which in non-amnionate Vertebrates persist throughout life as the urine-secretory organ, are superseded by the secondary kidneys. The actual primitive kidneys disappear almost entirely in the embryo at an early period, leaving but small traces. In the male Mammal the supplementary testis (*epididymis*) develops from the upper part of the primitive kidney; in the female the same part gives rise to a useless rudimentary organ, the supplementary ovary (*parovarium*).

In the female Mammal the Müllerian ducts undergo very considerable changes. The actual ovaries develop only from its upper part; the lower part widens out into a spindle-shaped pouch, with a thick, fleshy wall, within which the fertilized egg develops into the embryo. This pouch is the womb (*uterus*). At first the two uteri are perfectly separate, and open on each side of the urine-bladder (*vu*) into the cloaca, as is yet permanently the case in the lowest living Mammals, the Beaked Animals (*Ornithostoma*);

but even in Pouched Animals (*Marsupialia*) a connection forms between the two Müllerian ducts, and in Placental Animals they coalesce below with the rudimentary Wolffian ducts, forming with them a single "sexual cord" (*funiculus genitalis*). But the original independence of the two parts of the uterus, and of the two vagina canals which proceed out of their lower extremities, persists in many lower Placental Animals, while in the higher members of the same group, these organs gradually coalesce to form one single organ. The process of coalescence advances steadily from below (or from behind) upwards (or forwards). While in many Gnawing Animals (*Rodentia, e.g.,* Hares and Squirrels) two separate uteri open into the vagina canal which has already become simple, in other Gnawing Animals, as also in Beasts of Prey, Whales, and Hoofed Animals (*Ungulata*), the lower halves of the two uteri are already coalescent, their upper halves (the so-called horns, "*cornua*") remaining distinct ("*uterus bicornis*"). In Bats and Semi-apes these upper horns are very short, while the unified lower part becomes longer. Finally, in Apes, as in Man, the cohesion of the two parts is complete, one simple pear-shaped uterus-pouch alone remaining, and into this the oviducts open on each side.

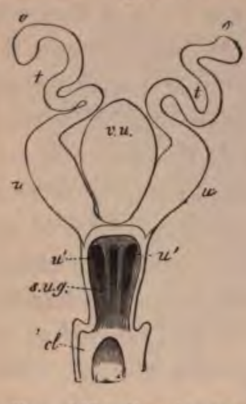


FIG. 327.—Female sexual organs of a Beaked Animal (*Ornithorhynchus*, Figs. 195, 196): *o*, ovaries; *t*, oviduct; *u*, uterus; *sug*, urinary sexual cavity (*sinus urogenitalis*); the two parts of the uterus open into this at *u'*: *cl*, cloaca. (After Gegenbaur.)

In the male Mammal also, a similar coalescence of the lower portion of the Müllerian and Wolffian ducts takes place. In this case also, these ducts form a single "sexual cord" (Fig. 325, *g*), which likewise opens into the original urinary sexual cavity (*sinus urogenitalis*), which develops from the lower part of the urinary bladder (*v*). While, however, in the male Mammal the Wolffian ducts develop into the permanent sperm-ducts, only very slight traces of the Müllerian ducts remain as rudimentary organs. The most remarkable of these is the "male uterus" (*uterus masculinus*), which originates from the lowest, coalescent portion of the Müllerian ducts, and which is homologous with the female uterus. It forms a small flask-shaped vesicle, entirely without physiological significance, which opens into the urinary tubes between the two sperm-ducts and the prostatic lobes (*vesicula prostatica*).

The internal sexual organs in Mammals undergo very peculiar modifications in point of position. At first the germ-glands, in both sexes, lie deep down in the ventral cavity, on the inner side of the primitive kidneys (Figs. 320, *g*, 321, *k*), attached to the vertebral column by a short mesentery (in the male, the *mesorchium;* in the female, *mesovarium*). It is only, however, in Monotremes that this original position of the germ-glands is (as in lower Vertetebrates) permanent. In all other Mammals (Marsupials as well as Placentals) these glands quit their place of origin and make their way more or less downward (or towards the posterior extremity), following the course of a cord which extends from the primitive kidney to the groin region of the abdominal wall. This is the groin-cord of the primitive kidney; in the male, the "Hunterian guiding-cord" (*guber-*

naculum testis) (Fig. 328, *M*, *gh*); in the female, the round uterus-cord (Fig. 328, *F*, *r*). In the latter the ovaries migrate more or less in the direction of the small pelvis, or

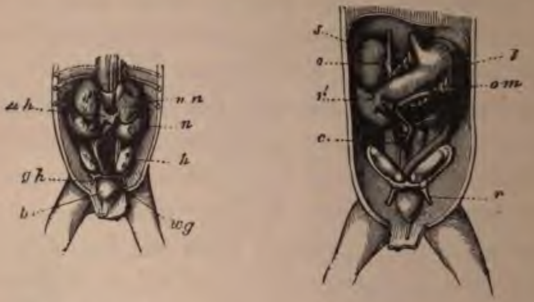


FIG. 328, *M*. FIG. 328, *F*.

FIG. 328.—Original position of the sexual glands in the abdominal cavity of the human embryo (of three months). Fig. 328, *M*, male (natural size): *h*, testis; *gh*, the conducting-cord of the testis; *wg*, seed-duct; *b*, urinary bladder; *uh*, lower hollow vein (*vena cava*); *nn*, supplementary kidneys; *n*, kidneys. Fig. 328 *F*, female (somewhat enlarged): *r*, round uterus-cord (below this the urine-bladder, above it the ovary); *r'*, kidney; *s*, supplementary kidney; *c*, blind-intestine (*cæcum*); *o*, small net; *om*, large net (between the two is the stomach); *l*, spleen. (After Kölliker.)

even enter this. In the male the testis quits the abdominal cavity altogether, passing through the groin-canal, and enters a sac-shaped, distended fold of the external skin-covering. The coalescence of the right and left folds ("sexual folds") gives rise to the testis-sac (*scrotum*). The various Mammals exhibit the various stages of this migration. In the Elephant and in Whales the testes descend very little, and lie below the kidneys. In many Gnawing Animals (*Rodentia*) and Beasts of Prey (*Carnaria*) they enter the groin-canal. In most higher Mammals they pass down through this into the testis-sac; usually the walls of the groin-canal coalesce. When, however, this remains open, the testes are able to descend periodically (in the rutting season) into the testis-sac, returning again into the abdominal cavity (*e.g.*, in Pouched Animals or *Marsupialia*, Gnawing Animals, Bats, etc.).

Another peculiarity of Mammals is the formation of the external sexual organs which, as copulative organs, serve to carry the fertilizing sperm from the male into the female organism in the act of copulation. Organs of this sort are altogether wanting in most lower Vertebrates. In those which are aquatic (*e.g.*, Acrania, Cyclostoma, and most Fishes) the eggs and sperm are simply discharged into the water, and their coming together is the result of some lucky accident which in this way brings about impregnation. On the other hand, in many Fishes and Amphibia which bring forth their young alive, there is a direct transfer of the sperm from the male to the female organism; and this is the case in all Amniota (Reptiles, Birds, and Mammals). In these animals the urinary and genital organs always open originally into the lower part of the rectum, which thus forms a "cloaca" (p. 345); but among Mammals the cloaca is permanent only in the Beaked Animals (*Ornithostoma*), which have, on this account, been called Cloacal Animals (*Monotrema*, Fig. 327, *cl*). In all other Mammals a lateral partition wall develops in the cloaca (in the human embryo about the middle of the third month), by which the latter is separated into two cavities. The urinary sexual canal passes into the anterior cavity (*sinus urogenitalis*), and it is through this cavity alone that the urinary and sexual products are discharged, while the "anal cavity," which lies behind it, serves merely to eject the excrement through the anus. Even before the appearance of this partition, in the Pouched Animals (*Marsupialia*) and Placental Animals, a conical papilla—the sexual protuberance (*phallus*, Fig. 329, *A*, *e*, *B*, *e*)—rises on the anterior part of the circumference of the cloaca-opening. The apex of this is swollen into a knob (the "acorn," *glans*). On the under side appears a furrow (*sulcus genitalis*, *f*), and on each side of the latter a skin-fold, or sexual fold (*hl*). The phallus is especially the organ of the "sexual sense," and over it are distributed the sexual

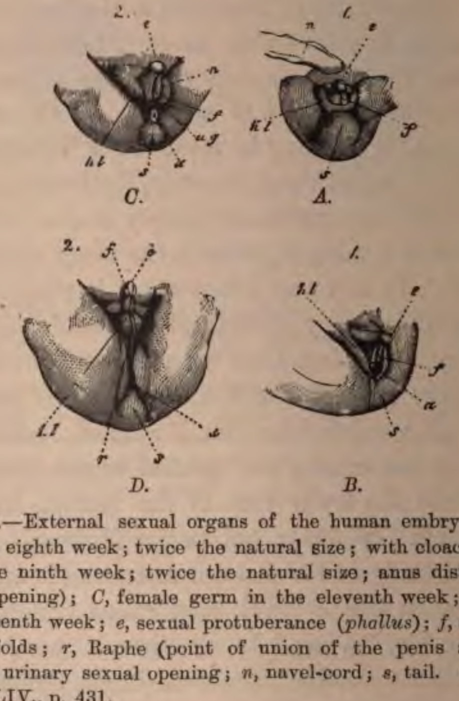


FIG. 329.—External sexual organs of the human embryo: *A*, neutral germ (in the eighth week; twice the natural size; with cloaca); *B*, neutral germ (in the ninth week; twice the natural size; anus distinct from the urogenital opening); *C*, female germ in the eleventh week; *D*, male germ in the fourteenth week; *e*, sexual protuberance (*phallus*); *f*, sexual furrow; *hl*, sexual folds; *r*, Raphe (point of union of the penis and scrotum); *a*, anus; *ug*, urinary sexual opening; *n*, navel-cord; *s*, tail. (After Ecker.) Cf. Table XLIV., p. 431.

nerves (*nervi pudendi*) which are especially concerned in producing the sexual sensations (p. 238). In the male the phallus develops into the masculine "*penis*" (Fig. 329, *D*, *e*); in the female it becomes the much smaller "*clitoris*" (Fig. 329, *C*, *e*); only in some Apes (*Ateles*) does this become unusually large. The "fore-skin" (*præputium*), in both sexes, also develops as a skin-fold from the anterior part of the circumference of the phallus. In the male sexual furrow the lower side of the phallus receives the urogenital canal, and, as a continuation of the latter, modifies, by the coalescence of its two parallel edges, into a closed canal—the male urinary tube (*urethra*). In the female this occurs only in a few instances (in some Semi-apes, Gnawing Animals or *Rodentia*, and Moles); as a rule the sexual furrow remains open and its edges are developed into the *labia minora*. The *labia majora* of the female develops from the two parallel skin-folds which appear on each side of the sexual furrow. In the male these last folds coalesce, forming a closed sac, the testis-sac (*scrotum*). Occasionally this coalescence does not take place, and the sexual furrow also sometimes remains open (*hypospadia*). In these cases the external male genitalia resemble the female, and this phenomenon has often been mistaken for hermaphroditism (pseudo-hermaphroditism).[197]

From this and other cases of false "hermaphroditism," the much less frequent cases of "true hermaphroditism" are very distinct. This exists only when the essential organs of reproduction, both kinds of germ-glands, are united in one individual. Either an ovary is then developed on the right, and a testis on the left (or *vice versa*); or testes and ovaries are developed on both sides, one more, the other less perfectly. As we have already seen that the original rudiment of the sexual organs is really hermaphroditic in all Vertebrates, and that the separation of the sexes is only due to a one-sided development of this hermaphroditic rudiment, these remarkable cases offer no theoretic difficulties. They very seldom, however, occur in Man and the higher Vertebrates. On the other hand, we find original hermaphroditism constant in some lower Vertebrates, as in some Fishes of the Perch kind (*Serranus*), and in some Amphibia (*Bombinator* and in Toads). In these cases, the male has usually a rudimentary ovary at the upper extremity of the testis; on the other hand, the female has sometimes a rudimentary testis, without function. This also occurs occasionally in Carp and some other Fishes. We have already seen how the original hermaphroditism is maintained in the excretory ducts, in Amphibia.

In the germ-history of the human urinary and sexual organs, the outlines of the history of human descent have been faithfully maintained up to the present time. We can trace their development in the human embryo step by step, in the same gradations as are exhibited, one after another, in the comparison of the urogenitals in Acrania, Cyclostomi, Fishes, Amphibians, and then further, in the series of Mammals, in Cloacal Animals (*Monotremes*), Pouched Animals (*Marsupialia*), and the various Placental Animals. (Cf. Table XLIII.) All the structural peculiarities of the urogenitals, distinguishing Mammals from other Vertebrates, are also present in Man; and in all special characteristics the latter resembles the Apes, and especially the Anthropoid Apes. As evidence that the special peculiarities of Mammals have been transmitted to Man, I will finally briefly notice the similar manner in which the eggs are formed in the ovary. In all Mammals, the mature eggs are contained in peculiar vesicles, which, after their discoverer, Regner De Graaf (1677), are called the Graafian follicles. These were formerly regarded as the actual eggs, which were, however, discovered by Baer *within* the Graafian follicles (vol. i. p. 55). Each follicle (Fig. 330, *C*) consists of a round, fibrous capsule, which contains fluid and is coated by several layers of cells. At one point this cellular layer has a knob-like enlargement (*C*, *b*), and, there, surrounds the real egg (*C*, *a*). The mammalian ovary is, originally, a very simple oblong little body (Fig. 320, *g*), formed only of connective tissue and blood-vessels, and surrounded by a cell-layer (the epithelium of the ovary, or the female germ-epithelium). From this epithelium, cords of cells grow inward, into the connective tissue or "stroma" of the ovary (Fig. 330, *A*, *b*). Single cells of these cords increase in size and become egg-cells (primitive eggs, *A*, *c*); but the greater number of the cells remain small and form an enveloping and nutritive cellular layer (the follicle-epithelium) round each egg.

In Mammals the follicle-epithelium is at first one-layered (Fig. 330, *B*, 1), afterwards many-layered (*B*, 2). In all other Vertebrates, the egg-cell is, indeed, enclosed in a permanent covering of small cells, an egg-follicle; but only in Mammals does fluid accumulate between the growing follicle-cells, and thus extends the follicle into a round bladder of considerable size, on the inner wall of which the egg lies excentrically. In this point, as in his whole Morphology, Man unmistakably indicates his descent from Mammals.

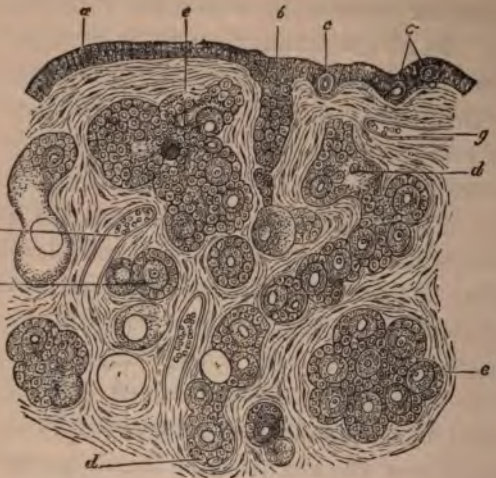


FIG. 330, *A*.

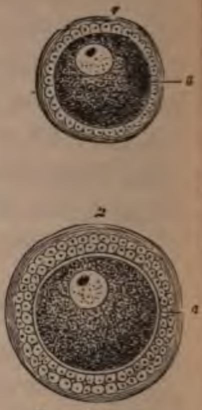


FIG. 330, *B*.

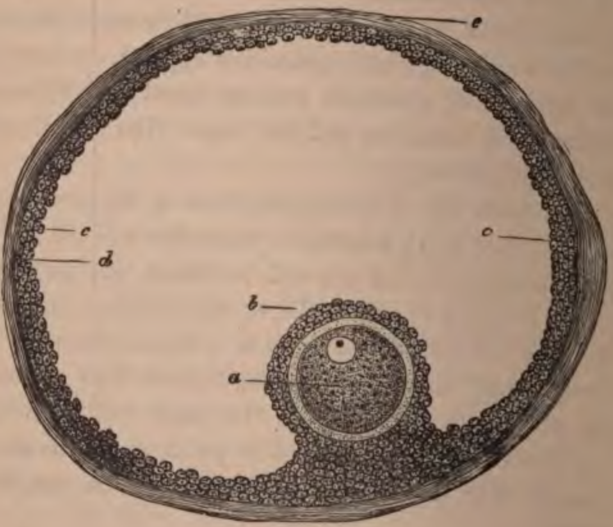


FIG. 330. *C*.

FIG. 330.—Development of human ovules within the female ovary.—*A.* Vertical section through the ovary of a new-born female: *a*, epithelium of the ovary; *b*, rudiment of an egg-cord; *c*, young eggs in the epithelium; *d*, longer egg-cord with the follicles; *e*, group of young follicles; *f*, single young follicle; *g*, blood-vessels in the connective tissue (*stroma*) of the ovary. In the cords the young primitive eggs can be distinguished from the surrounding cells of the follicle by their relatively large size. (After Waldeyer).—330, *B.* Two young follicles isolated; in 1, the cells of the follicle form but a single layer around the young primitive egg; in 2, they form a double layer; in 2, they begin to form the primary chorion (*a*), or the *zona pellucida* (vol. i. p. 135).—330, *C.* A mature human Graafian follicle: *a*, the mature egg; *b*, the surrounding follicle-cells; *c*, the epithelial cells of the follicle; *d*, the fibrous membrane of the follicle; *e*, its outer surface.

The entire natural history of the human sexual organs is one of the branches of Anthropology which affords the strongest proofs of the origin of the human race from the animal kingdom. Each man, on knowing the pertinent facts, and without prejudice, judging these comparatively, can but be convinced that he is descended from lower Vertebrates. The general, and the more minute structure, the activity and the individual evolution of the sexual organs, is exactly the same in Man as in Apes. This is as true of the male as of the female, of the internal as of the external genitalia. The differences in this matter between Man and the most man-like Apes are far less than the differences between the various forms of Apes. As, however, all Apes are undoubtedly from a common origin, this fact alone proves, with absolute certainty, the descent of Man from Apes.

TABLE XLIII.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE URINARY AND SEXUAL ORGANS OF MAN.[197]

XLIII. *A.* First main division: the sexual organs (G) and the urinary organs (U) are distinct. (The sexual or genital system (G) and the excretory or urinary system act independently of each other.)

I. *First Period: Genitals and Kidneys of Gastræads.*

G. Single, scattered cells of the entoderm change into egg-cells; single, scattered cells of the exoderm into sperm-cells.

U. Special urinary organs are as yet wholly wanting. Secretion is performed by the cells of the exoderm.

II. *Second Period: Genitals and Kidneys of Primitive Worms.*

G. The egg-cells of the entoderm gather into groups (ovary-plates); as do the sperm-cells of the exoderm (testis-plates).

U. A pair of simple pouch-like skin-glands (products of the skin-sensory layer) develop into extremely simple kidney-canals (excretory organs of the Flat-worms, *Platelminthes*).

III. *Third Period: Genitals and Kidneys of Scolecida.*

G. After the differentiation of the four secondary germ-layers is complete, the egg-cells pass from the skin-sensory layer into the skin-fibrous layer; the sperm-cells also pass from the intestinal-glandular layer into the intestinal-fibrous layer.

U. After the formation of the cœlom is completed, the blind inner ends of the two kidney-canals (or "primitive kidney ducts") open into the body-cavity (*cœloma*).

IV. *Fourth Period: Genitals and Kidneys of Chordonia.*

G. The groups of egg-cells (ovarial plates) and the groups of sperm-cells (testes-plates) meet at the boundary between the endocœlar (the visceral intestinal-fibrous layer of the cœlom-epithelium) and the exocœlar (the parietal skin-fibrous layer of the cœlom-epithelium), so as to form the hermaphrodite glands.

U. The primitive kidney ducts differentiate into an excretory and a glandular part.

V. *Fifth Period: Genitals and Kidneys of Acrania.*

G. The sexes become distinct. In the female, only the ovary is developed; in the male, only the testes.

U. The primitive kidney ducts remain simple (atrophied in *Amphioxus*).

VI. *Sixth Period: Genitals and Kidneys of Cyclostoma.*

G. The sexual glands (numerous in *Acrania*) coalesce into a pair.

U. The primitive kidney ducts send out lateral branches which acquire vascular coils (*glomeruli*) (the semi-pinnate primitive kidneys of *Bdellostoma*).

XLIII. *B.* Second main division: the genital organs (G) and the urinary organs (U) become united. (The sexual system and the urinary system are united in the "urogenital system.")

VII. *Seventh Period: Urogenitals of Primitive Fishes (Selachii).*

The primary primitive kidney duct differentiates on each side, forming two secondary canals; the Wolffian duct, which develops into the seed-duct, and the Müllerian duct, which develops into the oviduct. Both genital ducts originally open behind the anus (*Proselachii*).

VIII. *Eighth Period: Urogenitals of Dipneusta.*

A cloaca is formed by the union of the urogenital opening and the cavity of the anus. The single urinary bladder grows out from the anterior wall of the rectum (*Lepidosiren*).

IX. *Ninth Period: Urogenitals of Amphibia.*

From the uppermost part of the primitive kidney which is in process of atrophy, proceeds, in the male sex, the supplementary testis; in the female sex, the supplementary ovary. The Wolffian duct yet acts, in both sexes, as a urinary canal, and, in the male, also as the seed-duct. The Müllerian duct acts in the female sex as oviduct; in the male it is a rudimentary organ (Rathke's duct).

X. *Tenth Period: Urogenitals of Protamnia.*

The atrophied primitive kidney is replaced by the permanent secondary kidney as the urinary organ. The urinary bladder grows out from the ventral orifice of the embryo and forms the allantois. From the anterior wall of the cloaca grows the sexual protuberance (*phallus*), which, in the male, develops to the penis, in the female, to the clitoris.

XI. *Eleventh Period: Urogenitals of Monotremes.*

The lower end of the oviduct enlarges on each side to a muscular uterus.

XII. *Twelfth Period: Urogenitals of Marsupialia.*

The cloaca is separated by a partition into an anterior urogenital opening *apertura urogenitalis*) and a posterior anal opening (*anus*). From the lower part of the uterus the vagina-canal passes out on each side. The ovaries and testes begin to move downward from their place of formation.

XIII. *Thirteenth Period: Urogenitals of Semi-apes.*

The lower parts of the Müllerian and the Wolffian ducts coalesce into a sexual cord. The coalescence of the two uteri at the lower part gives rise to the *uterus bicornis*. A part of the allantois becomes the placenta.

XIV. *Fourteenth Period: Urogenitals of Apes.*

The two uteri coalesce throughout their entire length, forming a single pear-shaped uterus, as in Man.

TABLE XLIV.

Systematic Survey of the Homologies of the Sexual Organs in the two Sexes of Mammals.

XLIV. *A.* HOMOLOGIES OF THE INTERNAL SEXUAL ORGANS.

G. *Common Rudiments of the Internal Sexual Organs.*	M. *Internal Male Parts.*	F. *Internal Female Parts.*
1. Male germ-gland (testes-plate in the embryo, product of the skin-layer ?)	1. Testis (*Testis*, or *Orchis*)	1. Rudimentary testis disappears,—remains in some Amphibia
2. Female germ-gland (ovary-plate, product of the intestinal layer ?)	2. (Rudimentary ovary, disappears,—remains in some Amphibia)	2. Ovary (*Ovarium*, or *Oophoron*)
3. Wolffian duct (lateral primitive kidney duct)	3. Seed-duct (*Spermaductus*)	3. Gartnerian duct (rudimentary canal)
4 *a*. Müllerian duct (*Ductus Mülleri*, central primitive kidney duct)	4 *a*. Rathke's duct (rudimentary canal in Amphibia)	4 *a*. Oviduct (*Oviductus*, or *Tuba Fallopiæ*)
4 *b*. Upper part of the Müllerian duct	4 *b*. *Hydatis Morgagni*	4 *b*. *Hydatis Fallopiæ*
4 *c*. Lower part of the Müllerian duct	4 *c*. *Uterus masculinus* (*Vesicula prostatica*)	4 *c*. Uterus, sheath (*vagina*)
5. Remnant of the primitive kidney (*Protonephron, corpus Wolffii*)	5. Supplementary testes (*Epididymis*)	5. Supplementary ovary (*Parovarium*)
6. Groin ligament of the primitive kidney (*Ligamentum protonephroinguinale*)	6. Hunterian guiding-cord (*Gubernaculum Hunteri*)	6. Round uterus-cord (*Ligamentum uteri rotundum*)
7. Sexual mesentery (*Mesenterium sexuale*)	7. Testis-mesentery (*Mesorchium*)	7. Ovary-mesentery (*Mesovarium*)

XLIV. *B.* HOMOLOGIES OF THE EXTERNAL SEXUAL ORGANS.

G. *Common Rudiments of the External Sexual Organs.*	M. *External Male Parts.*	F. *External Female Parts.*
8. Sexual protuberance (*Phallus*)	8. Penis	8. Clitoris
9. Fore-skin (*Præputium*)	9. Male fore-skin (*Præputium penis*)	9. Female fore-skin (*Præputium clitoridis*)
10. Sexual folds (*Plicæ genitales*)	10. Testes-sac (*Scrotum*)	10. *Labia pudendi majores*
11. Fissure between the two sexual folds	11. Seam of the testis-sac (*Raphe scroti*)	11. Female *Vulva*
12. Sexual edges (edges of the sexual furrow)	12. Edges of the sexual furrow coalesce	12. *Labia pudendi minora*
13. Urogenital canal (*Sinus urogenitalis*)	13. Ureters (*Urethra*)	13. Antechamber of the vagina (*Vestibulum vaginæ*)
14. Glandular appendages of the urogenital canal	14. Cowper's glands	14. Bartholi's glands

CHAPTER XXVI.

RESULTS OF ANTHROPOGENY.

Review of the Germ history as given.—Its Explanation by the Fundamental Law of Biogeny.—Its Causal Relation to the History of the Tribe.—Rudimentary Organs of Man.—Dysteleology, or the Doctrine of Purposelessness.—Inheritances from Apes.—Man's Place in the Natural System of the Animal Kingdom.—Man as a Vertebrate and a Mammal.—Special Tribal Relation of Men and Apes.—Evidences regarding the Ape Question.—The Catarhina and the Platyrhina.—The Divine Origin of Man.—Adam and Eve.—History of the Evolution of the Mind.—Important Mental Differences within a Single Class of Animals.—The Mammalian Mind and the Insect Mind.—Mind in the Ant and in the Scale-louse (*Coccus*).—Mind in Man and in Ape.—The Organ of Mental Activity: the Central Nervous System.—The Ontogeny and Phylogeny of the Mind.—The Monistic and Dualistic Theories of the Mind.—Heredity of the Mind.—Bearing of the Fundamental Law of Biogeny on Psychology.—Influence of Anthropogeny on the Victory of the Monistic Philosophy and the Defeat of the Dualistic.—Nature and Spirit.—Natural Science and Spiritual Science.—Conception of the World reformed by Anthropogeny.

"The Theory of Descent is a general inductive law which results with absolute necessity from the comparative synthesis of all the phenomena of organic nature, and especially from the threefold parallel of phylogenetic, ontogenetic, and systematic evolution. The doctrine that man has developed from lower Vertebrates, and immediately from genuine Apes, is a special deductive conclusion, which results with absolute necessity from the general inductive law of the Theory of Descent. This view of 'man's place in nature,' cannot, we believe, be made too prominent. If the Theory of Descent is correct as a whole, then the theory that man has developed from lower Vertebrates is simply an unavoidable deductive conclusion from that general inductive law. Hence, all farther discoveries which may in future enrich our knowledge of the phyletic development of man, can only be confirmative of special points of that deduction, which rests on the broadest inductive basis."—*Generelle Morphologie* (1866).

As we have now traversed the wonderful territory of the history of human development, and learned its most important parts, it seems appropriate that, at the close of our travels, we should look back on the road behind us, and, on the other hand, glance forward along the further path of knowledge into which our road will lead in future. We started from the simplest facts of the history of man's individual development; ontogenetic facts which can, at any moment, be shown and established by microscopic or anatomic research. The first and most important of these ontogenetic facts is, that every man, like every other animal, is at the commencement of his individual existence, a simple cell. This egg-cell exhibits precisely the same structure and mode of origin as that of any other Mammal. From this cell proceeds, by repeated division, a many-celled body, the mulberry-germ (*morula*); this changes into a cup-germ (*gastrula*), and this, again, into an intestinal germ-vesicle (*gastrocystis*). The two distinct cell-strata which compose its wall are the two primary germ-layers; the skin-layer (*exoderma*) and the intestinal layer (*entoderma*). This double-layered germ-form is the ontogenetic reproduction of that extremely important phylogenetic parent-form of all Intestinal Animals, to which we have given the name Gastræa.

As the human germ, like that of other Intestinal Animals, passes through this gastrula-form, we are enabled to trace its phylogenetic origin back to the Gastræa. By tracing the germ-history of the two-layered germ still farther, we found that, by fission, four secondary layers are produced from the two original germ-layers. These have exactly the same constitution and genetic significance in Man as in all other Vertebrates. From the skin-sensory layer develops the outer skin (*epidermis*) and the central nervous system, and, probably, the kidney system. The skin-fibrous layer forms the leather-skin (*corium*) and the organs of motion (the skeleton and muscle systems). From the intestinal-fibrous layer originates the vascular system and the fleshy wall of the intestine. The intestinal-glandular layer, finally, forms only the epithelium, or the inner cellular layer of the intestinal-mucous membrane and of the intestinal glands.

The manner in which these various organic systems develop from the four secondary germ-layers, is, from the very first, exactly the same in Man as in all other Vertebrates. The germ-history of each separate organ afforded proof that the human embryo takes exactly the same special direction in its differentiation and formation, which, except in Man, occurs only in the other Vertebrates. Within this great animal tribe we then traced, step by step, and stage after stage, the farther development which takes place in the entire body as well as in all its several parts. This higher development takes place in the human embryo in the form peculiar to Mammals. Finally, we saw, that even *within* this class the various stages of phylogenetic development, which determine the natural classification of Mammals, correspond throughout to the various stages of ontogenetic formation through which the human embryo passes in the further course of its development. We were thus enabled to determine the place of Man more definitely in the system of this class, and accordingly to establish the nature of his relation to the various mammalian orders.

The course of reasoning which we adopted in explaining these ontogenetic facts, was simply the logical carrying out of the fundamental law of Biogeny. In so doing we have constantly tried to carry out the significant distinction between palingenetic and kenogenetic phenomena. Palingenesis, or "the history of inheritance," alone enabled us to draw direct conclusions from observed germ-forms as to the tribal forms transmitted by heredity. On the other hand, these conclusions were more or less endangered, wherever Kenogenesis, or "vitiated evolution," was introduced by new adaptations. The whole understanding of the history of individual evolution depends on the recognition of this most important relation. We stand here on the border-line which sharply divides the new from the old method of scientific investigation, the new from the old conception of the world. All the results of recent morphological research drive us with irresistible force to the recognition of this fundamental principle of Biogeny, and of its far-reaching consequences. These are, it is true, irreconcilable with the customary mythological ideas of the world, and with the powerful prejudices engrafted into us in early youth by theosophic instruction; but, without this fundamental law of Biogeny, without the distinction between Palingenesis and Kenogenesis, and without the Theory of Descent, upon which these are based, we are entirely unable to understand the facts of organic development; without these, we cannot afford the faintest explanation of any part of this great and wonderful world of phenomena. But, if we recognize the causal relation between the development of the germ and that of the tribe, if we recognize the true causal connection of Ontogeny and Phylogeny, which is expressed in that law, then the wonderful phenomena of Ontogeny explain themselves most simply; then the facts of germ-development appear but the necessary mechanical effects of the development of the tribe, conditioned by the laws of Heredity and Adaptation. The inter-operation of these laws among the everywhere-active influences of the struggle for existence, —or, as we may simply say with Darwin, Natural Selection, —is amply sufficient to explain to us the entire process of germ-history by the history of the tribe. Darwin's chief merit lies in the fact, that by the discovery of the interaction of the phenomena of Heredity and Adaptation, he prepared the way for a correct, logical understanding of the history of Evolution.

Among the numerous and important evidences that we have found for the truth of this view of our development history, I will only call attention here once more to the peculiarly valuable records of creation afforded by Dysteleology, or the doctrine of purposelessness, the science dealing with rudimentary organs. It is impossible to emphasize too often and too strongly the high morphological importance of those remarkable parts of the body, which are, physiologically, completely worthless and useless. In every system of organs we find, in Man and in all higher Vertebrates, some of these worthless primæval heirlooms, which have been inherited from our lower vertebrate ancestors. Thus, first, we find on the outer surface of the body a scanty rudimentary covering of hair, which is thicker only on the head, in the armpits, and on some other parts of the body. The short hairs on the greater part of the surface of our bodies are entirely useless, are without any physiological significance; they are the last scanty remains of the much more fully developed hairy covering of our Ape ancestors (p. 208). The sense-organs exhibit a series of the most remarkable rudimentary parts. As we have seen, the whole external shell of the ear, with its cartilages, muscles, and membranes, is, in Man, a useless appendage, destitute of the physiological importance that was formerly, erroneously, attributed to it. It is the atrophied remnant of the pointed, freely-moving, and much more highly developed mammalian ear, the muscles of which we retain, although we can no longer use them (p. 271). Again, we found, at the inner corner of the human eye, the remarkable little crescent-shaped fold, which is of no use to us, and is of interest only as being the last vestige of the nictitating membrane; of that third inner eyelid which is still of great physiological importance in Sharks and many Amnion Animals (p. 259). Numerous and interesting dysteleological proofs are also afforded by the apparatus of motion, both by the bony and the muscular systems. I will only cite the free, projecting tail of the human embryo, and the rudimentary caudal vertebræ developed in the latter, together with the pertinent muscles; this whole organ is entirely useless to Man, but is of great interest as the atrophied remnant of the long tail of our earlier Ape ancestors, which was composed of numerous vertebræ and muscles (p. 283). From these same ancestors we have also inherited various bone-processes and muscles, which were of great use to them in their climbing life among the trees, but with us have fallen out of use. At various points under the skin we also have entirely unused skin-muscles; vestiges of the largely developed skin-muscles of our lower mammalian ancestors. It was the function of this "panniculus carnosus" to contract and wrinkle the skin, as we may see any day done by horses to drive away flies. We still possess an active remnant of this great skin-muscle in the muscle of the forehead, by means of which we wrinkle the forehead and draw up the eyebrows; but we are no longer able to move at will another considerable remnant of it, the great skin-muscle of the neck (*platysma myoides*).

As in these animal organ-systems of our body, so also in the vegetative apparatus, we meet with many rudimentary organs, most of which we have incidentally noticed. I will only cite the remarkable thyroid gland (*thyreoidea*), the rudiment of the crop and the remnant of the ciliated groove (hypobranchial groove) present in Chordonia, Ascidia, and Arcrania, on the lower part of the gill-body (pp. 336, 353); also the vermiform process of the blind-intestine (*cœcum*) (p. 344). In the vascular system we find many useless ducts, the vestiges of disused vessels which were formerly active blood-channels; such, for instance, are the "*ductus Botalli*," between the lung-artery and the aorta, and the "*ductus venosus Arantii*," between the *vena portæ* and *vena cava*, and many others. The numerous rudimentary organs of the urinary and sexual systems (p. 415) are especially interesting. Most of these are developed in one sex and rudimentary in the other. Thus, in the male, the seed-ducts form from the Wolffian ducts, of which the only traces remaining in the female are the Gartnerian canals. On the other hand, from the Müllerian ducts in the female are developed the oviducts and the uterus; while in the male, only the lower extremities of these ducts remain, forming the useless male uterus *(vesicula prostatica)*. In the nipples and mammary glands, the male possesses other rudimentary organs which, as a rule, are functional only in the female (p. 204).

A closer anatomical examination of the human body would bring to our notice a number of other rudimentary organs, all of which can be explained only by the Theory of Descent. They are among the most important evidences for the truth of the mechanical theory of nature, and among the most overwhelming proofs against the prevailing teleological ideas of creation. If, in accordance with this latter view, Man and every other organism had been designed for his life-purpose from the beginning, and had been called into existence by an act of creation, the existence of these rudimentary organs would be an incomprehensible enigma; it would be impossible to understand why the Creator should have laid this useless burden on his creatures in their life-journey, so arduous at the best. On the other hand, by means of the Theory of Descent we can explain their existence in the most simple way, and say: The rudimentary organs are parts of the body, which, in the course of centuries, have gradually fallen out of use; organs which performed definite functions in our animal ancestors, but which, in us, have lost their physiological importance. They have become useless in consequence of our adaptation to new circumstances, but yet are transmitted from generation to generation by heredity, and have only slowly atrophied.

Like these rudimentary organs, so also all the other organs of our body have been transmitted to us from Mammals, and, immediately, from our Ape ancestors. The human body includes no single organ which is not inherited from Apes; but, by means of our fundamental law of Biogeny, we can trace the origin of our several systems of organs yet further down to various lower ancestral grades. Thus, for instance, we can say that we have inherited the earliest organs of our body, the outer-skin (*epidermis*) and the intestinal canal, from the Gastræads, the nervous and muscular systems from the lower Worms (*Archelminthes*), the vascular system, body-cavity (*cœloma*), and blood from Soft Worms (*Scolecida*), the notochord and the gill-intestine from Chorda Animals, the differentiated organs of sense from the Cyclostoma, the limbs and the Müllerian ducts from Primitive Fishes (*Selachii*), and the external reproductive organs from Primitive Mammals (*Promammalia*). When we stated the "law of the ontogenetic connection of systematically allied forms," and determined the relative age of the organs, we saw how we could draw such phylogenetic conclusions as these from the ontogenetic succession of the organ-systems (vol. i. p. 390; ii. 357).

By the help of this important law and of Comparative Anatomy, we were also enabled to determine definitely "man's place in nature," or, as we may say, to assign to man his position in the system of the animal kingdom. It is now usual, in the more recent zoological systems, to distribute the whole animal kingdom into the seven tribes, or *phyla*, which are again sub-divided, in round numbers into about forty classes; and these classes into about two hundred orders. According to his whole organization, Man is undoubtedly, primarily, a member of but a single tribe, that of Vertebrates; secondly, he is a member of but a single class, that of Mammals; and, thirdly, a member of but a single order, that of the Apes. All the characteristic peculiarities, distinguishing Vertebrates from the other six tribes, distinguishing Mammals from the other forty classes, and distinguishing Apes from the remaining two hundred orders of the animal kingdom, are also present in Man. Turn and twist as we may, we cannot escape this anatomical and systematic fact. Quite recently this very fact has led to the liveliest discussion, and has occasioned, especially, many disputes about the specific anatomical relationship of Man to Apes. The most astounding views on this "ape question," or "pithecoid theory," have been uttered. It will therefore be well to examine it closely once more at this point, and to separate the essential from the non-essential in it.

We will start from the undisputed fact, that Man, at all events,—whether his special blood-relationship to Apes is acknowledged or denied,—is a genuine Mammal, is a Placental Mammal. This fundamental truth can be so easily proved at any moment by investigations in Comparative Anatomy, that it has been unanimously acknowledged since the separation of the Placental from the lower Mammals (Pouched Animals, or *Marsupialia*, and Beaked Animals, or *Ornithostoma*). But, from this, every logical adherent of the doctrine of development at once draws the conclusion, that man is descended from one and the same common parent-form, together with all other Placental Animals, from the progenitor of the *Placentalia*, just as, further, we must *necessarily* suppose a common mammalian ancestral form of all the various Mammals (*Placentalia*), Pouched Animals, and Cloacal Animals (*Monotremata*); but by this the great, all-agitating main question of man's place in nature is conclusively settled, whether we ascribe to Man a nearer or a more remote relationship to Apes. No matter whether Man is, in a phylogenetic sense, a member of the Ape order (or, if it is preferred, of the Primate order) or not,—in any case, his direct blood-relationship to all other Mammals, and especially to the Placental Mammals, is established. It may be that the inter-relations of the various Mammals are quite different from those now hypothetically assumed; but, in any case, the common descent of Man and all other Mammals from a common parent-form is indisputable. This primæval, long since extinct parent-form, which probably developed during the Triassic Period, was the monotreme ancestral form of all Mammals.

If this fundamental and extremely significant principle is borne in mind, the "ape question" will appear to us in a wholly different light from that in which it is usually presented. A little reflection will bring conviction that this question has not the importance that has of late been attributed to it; for the origin of the human race from a series of various mammalian ancestors, and the historical development of the latter from an earlier series of lower vertebrate ancestors, remains indubitably established, no matter whether the genuine "Apes" are regarded as the nearest animal ancestors of the human race or not. But, it having become habitual to lay the principal weight of the entire question of the origin of man on this very "descent from Apes," I find myself compelled to return once more to it here, and to recall those facts in Comparative Anatomy and Ontogeny, which conclusively settle this "ape question."

The shortest way to the goal is the one taken by

Huxley in his celebrated work, which we have so often quoted, on the "Evidences as to Man's Place in Nature,"—the way afforded by Comparative Anatomy and Ontogeny. We have to compare objectively all the several organs of Man with the same organs in the higher Apes, and then to ascertain whether the differences between the former and the latter are greater than the corresponding differences between the higher and lower Apes. The indubitable and indisputable result of this comparative anatomical investigation which was conducted with the greatest candour and accuracy, was the important law, which, in honour of its discoverer, we have named *Huxley's Law;* namely, that the physical differences between the organization of Man and that of the most highly developed Apes known to us, are much smaller than the corresponding differences between the higher and lower Apes. We might even define this law yet more exactly by excluding entirely the Platyrhina or American Apes as being more remote relatives, and limiting our comparison to the narrower circle of relatives, the Catarhina, or Apes of the Old World. Even within this small group of Mammals, we found the differences of structure between the higher and lower Narrow-nosed Apes, for example between the Gorilla and the Baboon, much greater than the differences between these Man-like Apes and Man When, in addition, we now turn to Ontogeny, and when we find there, according to our "law of the ontogenetic connection of systematically related forms, that the embryos of Man and of the Man-like Apes, are identical for a longer period than the embryos of the highest and of the lowest Apes, we are certainly obliged to bring ourselves, whether with a good or a bad grace, to acknowledge our origin from the Ape order. From the facts exhibited by Comparative Anatomy, we can undoubtedly form in imagination an approximate image of the structure of our ancestors during the older Tertiary Period; we may fill out the details as we will, yet this image will be a genuine Ape, and a true Catarhine. For Man has all the physical characters distinguishing the Catyrhina from the Platyrhina. Accordingly, in the mammalian pedigree, we must derive the human race directly from the Catarhine group, and refer the origin of Man to the Old World. For the entire group of the Catarhine Apes has, as yet, been confined to the Old World, just as the group of the Platyrhine Apes has been limited to the New. Only the earliest root-form, that from which both groups sprang, was common to them; probably it originated from the Semi-apes of the Old World.

Therefore, although it is thus indubitably established as the result of our objective scientific inquiry, that the human race is directly descended from the Apes of the Old World, yet we will once more state emphatically that this significant fact is not of as great importance to the main question of the origin of Man, as is generally supposed. For, even if we entirely ignore the fact or thrust it aside, this will not affect all that the zoological facts of Comparative Anatomy and the history of development have taught us concerning the placental character of Man. These clearly prove the common descent of Man and the other Mammals. It is evident also, that the main question cannot be in the least evaded or set aside by the statement: "Man is, indeed, a Mammal; but he branched off from the others quite at the root of the class, and has no nearer relationship with any other extant Mammal." At all events, the relationship is evidently more or less close if we comparatively examine the relation of the Mammalian class to the remaining forty classes of the animal kingdom. All Mammals, including Man, are, at least, of common origin, and it is equally certain that their common parent-forms gradually developed from a long series of lower Vertebrates.

Feeling, evidently, rather than understanding, induces most people to combat the theory of their "descent from Apes." It is simply because the organism of the Ape appears a caricature of Man, a distorted likeness of ourselves in a not very attractive form, because the customary æsthetic ideas and self-glorification of Man are touched by this in so sensitive a point, that most men shrink from recognizing their descent from Apes. It seems much pleasanter to be descended from a more highly developed, divine being, and hence, as is well known, human vanity has, from the earliest times, flattered itself by assuming the original descent of the race from gods or demi-gods. The church, with that sophistical distortion of ideas of which she is so great an adept, has managed to extol this ridiculous pride as Christian humility; and those people who reject with haughty horror every suggestion of descent from lower animals, and consider themselves children of God, those very people are exceedingly fond of boasting about their childlike humility of spirit. In most of the sermons delivered against the progress of the doctrine of evolution, human vanity and conceit play throughout a prominent part; and, although we have inherited this characteristic weakness from Apes, yet we must confess to having developed it to a degree of perfection which completely overthrows the unprejudiced judgment of the "sound understanding of man." We ridicule the childish follies occasioned by the pride of ancestry among the nobility, from the splendid Middle Ages down to our own time, and yet no small portion of this groundless pride of nobility lurks in a great majority of men. Just as most people prefer to trace their pedigree from a decayed baron or, if possible, from a celebrated prince, rather than from an unknown, humble peasant, so they prefer seeing the progenitor of the human race in an Adam degraded by the Fall, rather than in an Ape capable of higher development and progress. It is a matter of taste, and such genealogical preferences do not, therefore, admit of discussion. Still I must confess that, personally, I am as proud of my paternal grandfather, who was simply a Silesian peasant, as of my maternal grandfather, who raised himself from the position of a Rhenish lawyer to the highest posts in the council of state. And it is also much more to my individual taste to be the more highly developed descendant of a primæval Ape ancestor, who, in the struggle for existence, had developed progressively from lower Mammals, as they from still lower Vertebrates, than the degraded descendant of an Adam, god-like, but debased by the Fall, who was formed from a clod of earth, and of an Eve, created from a rib of Adam. As regards this celebrated "rib," I must here expressly add as a supplement to the history of the development of the skeleton, that the number of ribs is the same in man and in woman. In the latter as well as in the former, the ribs originate from the skin-fibrous layer, and are to be regarded phylogenetically as lower or ventral vertebræ (p. 285).

Now I certainly hear some one say: "That may all be right and correct as far as the human body is concerned, and, from the facts presented, it is certainly no longer to be doubted that this has actually developed gradually, step by step, from the long ancestral series of Vertebrates; but it is quite otherwise with the 'spirit of man,' with the human mind, which cannot possibly have developed in a similar way from the mind of lower Vertebrates." Let us see if the known facts of Comparative Anatomy, Physiology, and Evolution can meet this grave objection. We shall best gain firm ground from which to start in this matter by comparatively examining the minds of the different Vertebrates. Side by side within the various classes, orders, genera, and species of Vertebrates, we find so great a variety of vertebral intellects, that, at first sight, one can scarcely deem it possible that they can all be derived from the mind of a common "Primitive Vertebrate." First, there is the little Lancelet, which has no brain at all, but only a simple medullary tube, the entire mental capacity remaining at the very lowest grade occurring among Vertebrates. The Cyclostomi, also, standing just above, exhibit a hardly higher mental life, though they have a brain. Passing on to Fishes, we find their intelligence, as is well known, also at a very low point. Not until from these we ascend to the Amphibia, is any essential progress in mental development observable. This is much greater in Mammals, although, even here, in the Beaked Animals (*Ornithostoma*), and the next higher class, the stupid Pouched Animals (*Marsupials*), the entire mental activity is still of a very low order; but if we pass on from these to Placental Animals, within this multiform group we find such numerous and important steps in differentiation and improvement, that the mental differences between the most stupid Placental Animals (for instance, Sloths and Armadillos) and the most intelligent animals of the same group (for instance, Dogs and Apes), seem much more considerable than the intellectual differences between those lowest Placentals and the Pouched Animals, or even the lower Vertebrates. Those differences are, at any rate, much more considerable than the differences in the intellectual life of dogs, apes, and men. And yet all these animals are allied members of a single class.[198]

This fact is shown to a yet more surprising degree in the Comparative Psychology of another class of animals, which is specially interesting for many reasons, that of Insects. It is well known that many Insects exhibit a mental capacity approximately as highly developed as is possessed by Man only of the vertebrate group. It is needless to speak of the celebrated organized communities and states of Bees and Ants; every one knows that very remarkable social arrangements occur among these, such as occur in an equal degree of development only in the higher races of men, and nowhere else in the animal kingdom. I will only allude to the civil organization and government among Monarchical bees and Republican ants, to their division into various orders: the queen, the drone nobility, the workers, the nurses, soldiers, and so on. Among the most remarkable phenomena in this extremely interesting field of life, is certainly the cattle-keeping of certain Ants, which tend plant-lice for the sake of their milk and regularly collect their honey-juice. Even more remarkable is the slave-holding of the large red Ants, which steal the young of the small black species and rear them to slave-labour. It has long been known that all these civil and social arrangements of the Ants were originated by the systematic co-operation of numerous citizens, understanding each other. Numerous observations have placed the astoundingly high intellectual development of these little Articulated Animals beyond all doubt. With this let us compare, as Darwin has done, the intellectual capacity of many lower, and, especially, of many parasitic, Insects. There, for example, are the Scale Insects (*Coccus*) which, when mature, consist of an entirely immovable shield-shaped body attached to the leaves of plants. Their feet are atrophied. Their mouths are embedded into the tissue of the plant, the juices of which they suck. The whole mental activity of this motionless female parasite consists in the enjoyment it derives from sucking these juices and from sexual intercourse with the unattached male. The same is true of the maggot-like female of the Twisted-wings (*Strepsiptera*), which spends its whole life, wingless and footless, as a motionless parasite in the body of the wasp. There can be no suspicion of any higher mental activity there. If these brutish parasites are compared with the mentally active and sensible ants, it will certainly be admitted, that the psychical differences between the twc are much greater than those between the highest and lowest Mammals, between Beaked Animals (*Ornithostoma*), Pouched Animals (*Marsupialia*), and Armadillos on the one hand, and Dogs, Apes, and Men on the other. And yet all those insects belong, without question, to the single class of Arthropoda, just as all these Mammals undoubtedly belong to the single class of Vertebrates ; and just as every logical adherent of the doctrine of evolution must assume a common parent-form for all those Insects, so also he must necessarily assert a common descent for all these Mammals.

Turning now from observing the comparative mental capacity of the various animals to the question as to the organs of these functions, we receive the answer, that in all higher animals they are invariably connected with certain groups of cells, those cells which compose the central nervous system. All naturalists, without exception, agree that the central nervous system is the organ of the mental life of animals, and this assertion is at any time capable of experimental proof. If the central nervous system is wholly or partially destroyed, the "mind," or the psychical activity of the animal, is wholly or partially annihilated at the same time. We must, therefore, next inquire what is the character of the mental organ in man. The undeniable answer to this question has already been given. Man's mental organ is, in its whole structure and origin, the same as that of all other Vertebrates. It originates as a simple medullary tube from the outer skin of the embryo, from the skin-sensory layer, or the first of the secondary germ-layers. In the course of its gradual development it passes through the same stages of progression in the human embryo as in that of all other Vertebrates, and as these latter have undoubtedly a common origin, so must also the brain and spinal cord be of the same origin in all.

Physiological observation and experiment teaches, moreover, that the relation of the "mind" to its organ, the brain and spinal marrow, is exactly the same in Man as in all other Mammals. The former can in no case act without the latter; the one is connected with the other, as is muscular movement with muscle. Therefore, the mind can develop only in connection with its organ. Adherents of the Theory of Descent, who concede the causal connection between Ontogeny and Phylogeny, are now compelled to recognize the following propositions: The mind, or "psyche," of man has developed together with, and as the function of the medullary tube, and just as even now the brain and spinal marrow develop in each human individual from the simple medullary tube, so the human "mind," or the mental capacity of the entire human race, has developed gradually, step by step, from the mind of lower Vertebrates. Just as even now in every individual of the human race the wonderful and complex structure of the brain develops step by step from exactly the same rudiment, from the same five simple brain-bladders, as in all other Skulled Animals (*Craniota*), so the human mind has gradually developed in the course of millions of years from the mind of lower Skulled Animals; and as now the brain of every human embryo differentiates according to the special type of the Ape-brain, so also the human psyche has historically differentiated from the Ape-mind.

This monistic idea will, of course, be indignantly rejected by most people, who accept the contrary dualistic view, which denies the inseparable connection of the brain and the mind, and regards "body and mind" as entirely separate and distinct; but how shall we reconcile this commonly accepted view with the facts taught by the history of evolution? The dualistic view is, at least, as irreconcilably opposed to Ontogeny as to Phylogeny. If we agree with the majority of men, that the mind is a self-existent, independent being, which has originally nothing to do with the body, but only dwells in it for a time, and which gives expression to its emotions through the brain, as the piano-player through his instrument, then we must suppose a period in the human germ-history, at which the mind enters the body, enters the brain; and we must also suppose a moment at death, at which it leaves the body; and further, as every man inherits certain individual mental qualities from each parent, we must suppose that portions of the mind of each were transferred to the germ at the time of its procreation. A little piece of the father's mind accompanied the sperm-cell, a little piece of the mother's mind remained with the egg-cell. This dualistic view entirely fails to explain the phenomena of evolution. We all know that the new-born child has no consciousness, no knowledge of itself and of the objective world. Whoever has children of his own, and follows their mental development candidly, cannot possibly deny that processes of biological evolution are at work there. Just as all other functions of the body develop in connection with their organs, so does the mind develop in connection with the brain. And this gradual development of the child's mind is such a wonderful and beautiful phenomenon, that every mother and every father with eyes to see takes unwearied delight in observing it. The text-books of Psychology alone are ignorant of any such development, and we are almost forced to the conclusion that their authors themselves never had any children. The human mind, as it is represented in the great majority of psychological works, is only the one-sided mind of a learned philosopher, who, indeed, knows many books, but nothing of the process of evolution, and does not suspect that even his own mind has developed.

These same dualistic philosophers must, of course, if they are consistent, also assume that there was a moment in the Phylogeny of the human mind at which this mind first entered the vertebrate body of man. Accordingly, at the time when the human body developed from the body of the Anthropoid Ape (thus, probably, in the latter part of the Tertiary Period), a specific human mind-element—or, as it is usually expressed, a "divine spark"—must have suddenly entered or been breathed into the brain of the Anthropoid Ape, and there have associated itself with the already existing Ape-mind. I need not point out the theoretic difficulties involved in this conception. I will only remark that even this "divine spark," by which the mind of Man is said to be distinguished from that of all other animals, must itself be a thing capable of evolution, and has actually developed progressively in the course of human history. This "divine spark" is usually understood to be "reason," and is ascribed to man as a mental function distinguishing him from all "irrational animals." Comparative Psychology, however, teaches that this frontier-post between man and beast is altogether untenable.[198] We must either take the idea of reason in its broader sense, in which case it belongs to the higher Mammals (the Ape, Dog, Elephant, Horse), as much as to the majority of men; or we must conceive it in its narrower sense, and then it is lacking in the majority of men, as well as in most animals. On the whole, that which Goethe's Mephistopheles said of his time, is true of Man's reason to-day:

> "He might have kept himself more right
> Hadst Thou ne'er shewn to him a glimpse of heaven's light.
> He calls it Reason, but Thou seest
> Its use but makes him beastlier than the beast."

If, therefore, we must abandon this generally preferred, and, in many respects, very pleasant dualistic theory of the mind, as being wholly untenable, because irreconcilable with genetic facts, then the opposite monistic view alone remains to us, according to which the human mind, like that of any other animal, is a function of the central nervous system, with which it has developed in inseparable connection. Ontogenetically, we see this in every child; phylogenetically, we must assert it in accordance with the fundamental law of Biogeny. In every human embryo the medullary tube develops from the skin-sensory layer, and from the anterior part of that tube the five brain-bladders of Skulled Animals (*Craniota*), and from these the mammalian brain (at first with the characteristics of the lower, then with those of the higher Mammals). Just as this entire ontogenetic process is but a short reproduction, occasioned by Heredity, of the same process in the Phylogeny of Vertebrates, so also the wonderful mental activity of the human race has gradually developed, step by step, in the course of many thousands of years, from the less perfect mental activity of the lower Vertebrates. And the evolution of the mind in each child is only a brief reproduction of that long phylogenetic process.

The extraordinary and important bearing of Anthropogeny on Philosophy, in the light of the fundamental principle of Biogeny, now becomes apparent. The speculative philosophers who will take possession of the facts of Ontogeny and explain them phylogenetically (according to that law), will introduce a greater advance in the history of Philosophy than has been made by the greatest thinkers of all previous centuries. Undoubtedly every clear and logical thinker must draw from the facts of Comparative Anatomy and Ontogeny which have been brought forward, a mass of suggestive thoughts and reflections which cannot fail of their effect on the further development of the philosophical study of the universe. Neither can it be doubted that these facts, if properly weighed, and judged without prejudice, will lead to the decisive victory of that philosophical tendency, which we distinguish, briefly, as monistic or mechanical, in distinction from the dualistic or teleological, on which most philosophical systems of ancient, mediæval, and modern times are based. This mechanical, or monistic philosophy, asserts that everywhere the phenomena of human life, as well as those of external nature, are under the control of fixed and unalterable laws, that there is everywhere a necessary causal connection between phenomena, and that, accordingly, the whole knowable universe forms one undivided whole, a "*monon.*" It further asserts, that all phenomena are produced by mechanical causes (*causæ efficientes*), not by pre-arranged, purposive causes (*causæ finales*). Hence there is no such thing as "free-will" in the usual sense. On the contrary, in the light of this monistic conception of nature, even those phenomena which we have been accustomed to regard as most free and independent, the expressions of the human will, appear as subject to fixed laws as any other natural phenomenon Indeed, each unprejudiced and searching test applied to the action of our "free-will" shows that the latter is never really free, but is always determined by previous causal conditions, which are eventually referable either to Heredity or to Adaptation. Accordingly, we cannot assent to the popular distinction between nature and spirit. Spirit exists everywhere in nature, and we know of no spirit outside of nature. Hence, also, the usual distinction between natural science and mental science is entirely untenable. Every real science is at the same time both a natural and a mental science. Man is not above nature, but in nature.

The opponents of the doctrine of evolution are very fond of branding the monistic philosophy grounded upon it as "materialism," by confusing *philosophical* materialism with the wholly different and censurable *moral* materialism. Strictly, however, our "monism" might, as accurately or as inaccurately, be called spiritualism as materialism. The real materialistic philosophy asserts, that the vital phenomena of motion, like all other phenomena of motion, are effects or products of matter. The other, opposite extreme, spiritualistic philosophy, asserts, on the contrary, that matter is the product of motive force, and that all material forms are produced by free forces entirely independent of the matter itself. Thus, according to the materialistic conception of the universe, matter, or substance, precedes motion, or active force. According to the spiritualistic conception of the universe, on the contrary, active force or motion precedes matter. Both views are dualistic, and we hold them both to be equally false. A contrast to both views is presented in the *monistic* philosophy, which can as little believe in force without matter, as in matter without force. It is only necessary to reflect on this for a time, from a strictly scientific standpoint, to find that on close examination it is impossible clearly to represent the one without the other. As Goethe says, "Matter can never exist and act without spirit; neither can spirit without matter."[12]

The "spirit" and "mind" of man are but forces which are inseparably connected with the material substance of our bodies. Just as the motive force of our flesh is involved in the muscular form-element, so is the thinking force of our spirit involved in the form-element of the brain. Our spiritual forces are as much functions of this part of the body, as every force is a function of a material body. We know of no matter which does not possess force, and, conversely, of no forces that are not connected with matter. When the forces manifest themselves in the phenomena of motion, they are called active forces; if, on the other hand, the forces are in a state of rest, or of equilibrium, they are called latent forces.[199] This is as true of inorganic natural substances as of organic. The magnet attracting iron-filings, powder exploding, steam driving the locomotive, are active inorganic substances; they work by active force just as does the sensitive mimosa, when it folds its leaves at a touch,—as does the Amphioxus, when it buries itself in the sand,—as does man, when he thinks. Only in these latter cases the combination of the different forces, appearing as phenomena of motion, are much more complex and much less easily recognized than in the former cases.

Anthropogeny has led us to the conclusion that even in the entire history of the evolution of man, in the history of the germ, as well as in that of the tribe, no other active forces have been at work, than in the rest of organic and inorganic nature. All the forces at work there can be reduced at last to *growth*—to that fundamental function of evolution by which the forms of inorganic, as well as of organic bodies, originate. Growth, again, itself rests on the attraction and repulsion of like and unlike particles.[194] It has given rise to Man and to Ape, to Palm and Alga, to crystal and water. Hence the evolution of man has taken place according to the same "eternal, immutable laws," as has the evolution of any other natural body.

It is true that the prejudices that stand in the way of the general recognition of this "Natural Anthropogeny" are even yet intensely powerful; otherwise the ancient strife between the various philosophical systems would already have been decided in favour of "Monism." But it can be foreseen with certainty that a more general acquaintance with genetic facts, will gradually destroy those prejudices and bring about the victory of the natural idea of "Man's Place in Nature." The fear is often expressed in opposition to this view that it will cause a retrogression in the intellectual and moral development of man; but, on the contrary, I cannot withhold my conviction, that the very reverse will be true, that by it the progressive development of the human spirit will be advanced in an unusual degree. At all events, I hope and trust that I have, in these chapters, afforded convincing proof that the only way to attain a true scientific knowledge of the human organism, is by employing the method which we must acknowledge to be alone correct and successful in the study of organic nature,—by following the course of the History of Evolution.[200]

NOTES.

REMARKS AND REFERENCES TO LITERATURE.

1 (vol. i. p. 2). Anthropogeny (Greek) = History of the Evolution of Man; from Anthropos (ἄνθρωπος) = man, and genea (γενεά) = Evolution history. There is no especial Greek word for "the history of evolution;" in its place is used either γενεά (= descent), or γονέια (= generation). If goneia is preferred to genea, the word must be written Anthropogony. The word "*Anthropogony*," used first by Josephus, means, however, only "the generation of man." Genesis (γένεσις) means "origination, or evolution;" therefore *Anthropogenesis* = "the evolution of man."

2 (i. 3). Embryo (Greek) = germ (ἔμβρυον). Really τὸ ἐντὸς τῆς γαστρὸς βρύον (Eust.), *i.e.* the unborn germ in the mother's body (Latin fœtus, or, better, fetus). In accordance with this original sense, the term embryo should only be applied to those young organisms which are still enclosed in the egg-coverings. (Cf. "Generelle Morphologie," vol. ii. p. 20.) Inaccurately, however, various free-moving young forms of low animals (larvæ) are often spoken of as embryos. Embryonic life ends at birth.

3 (i. 5). Embryology (Greek) = Germ-science, from embryon (ἔμβρυον) = germ, and logos (λόγος) = science. Even now the whole history of the evolution of the individual is erroneously called "embryology." For corresponding with the term "embryo" (see note 2), by "embryology," or "embryogony," should only be understood "the history of the evolution of the

individual within the egg-coverings." As soon as the organism has left there, it is no longer a real "embryo." The later changes of this form the subject of the science of Metamorphoses, or *Metamorphology.*

4 (i. 5). Ontogeny (Greek) = "germ-history," or "the history of the evolution of the individual;" from ὄντα = individuals, and genea (γενεά) = history of evolution. (Cf. note 1.) Ontogeny, as the "history of the evolution of the individual," embraces both Embryology and Metamorphology (note 3).—"Generelle Morphologie," vol. ii. p. 30.

5 (i. 5). Phylogeny (Greek) = tribal history, or "the palæontological history of evolution;" from phylon (φὺλον) = tribe, and genea (γενεά) = history of evolution. The phylon includes all organisms connected by blood, which are descended from a common typical parent-form. Phylogeny includes Palæontology and Genealogy.—"Generelle Morphologie," vol. ii. p. 305.

6 (i. 6). Biogeny (Greek) = the history of the evolution of organisms or of living natural bodies in the widest sense. (Genea tu biu.) βίος = life.

7 (i. 6). The fundamental law of Biogeny. Cf. my "General History of the Evolution of Organisms" ("Generelle Morphologie," 1866, vol. ii.), p. 300 (Essays on the causal connection of biogenetic and phyletic evolution); also the "Monograph of Chalk Sponges" ("Monographie der Kalkschwämme," 1872, vol. i. 471); also my "Natural History of Creation."

8 (i. 10). Palingenesis (Greek) = original evolution, from palingenesia (παλιγγενεσία) = new-birth, renewal of the former course of evolution. Therefore, Palingeny = inherited history (from παλιν = reproduced, and γενεά = history of evolution).

9 (i. 10). Kenogenesis (Greek) = modified evolution, from kenos (κενός) = strange, meaningless; and genea (γενεά) = history of evolution. The modifications introduced into Palingenesis by Kenogenesis are vitiations, strange, meaningless additions to the original, true course of evolution. Kenogeny = vitiated history.

10 (i. 12). Latin definition of the fundamental law of

Biogeny: "Ontogenesis summarium vel recapitulatio est phylogeneseos, tanto integrius, quanto hereditate palingenesis conservatur, tanto minus integrum, quanto adaptatione kenogenesis introducitur." Cf. my "Aims and Methods of Recent History of Evolution" ("Ziele und Wege der Heutigen Entwickelungsgeschichte," p. 77. Jena, 1876).

11 (i. 17). Mechanical and purposive causes. **Mechanical** natural philosophy assumes that throughout nature, in organic as well as in inorganic processes, only non-purposive, mechanical, necessarily-working causes exist (*causæ efficientes, mechanism, causality*) On the other hand, vitalistic natural philosophy asserts that the latter are at work only in inorganic processes, which in certain other, purposive, special causes are at work, conscious or purposive causes, working for a definite end (*causæ finales, Vitalism, Teleology*). (Cf. "Generelle Morphologie," vol. i. p. 94.)

12 (i. 17). Monism and Dualism. **Unitary** philosophy, or Monism, is neither extremely materialistic nor extremely spiritualistic, but resembles rather a union and combination of these opposed principles, in that it conceives all nature as one whole and nowhere recognizes any but mechanical causes. Binary philosophy, on the other hand, or Dualism, regards nature and spirit, matter and force, inorganic and organic nature as distinct and independent existences. (Cf. vol. ii. p. 456.)

13 (i. 20). Morphology and Physiology. Morphology (as the science of forms) and Physiology (as the science of the functions of organisms) are indeed connected, but co-ordinate sciences, independent of each other. The two together constitute Biology, or the "science of organisms." Each has its peculiar methods and aids. (Cf. "Generelle Morphologie," vol. i. pp. 17–21.)

14 (i. 24). Morphogeny and Physiogeny. Biogeny, or the "history of the evolution of organisms," up to the present time has been almost exclusively Morphogeny. Just as this first opens the way to a true knowledge of organic forms, so will Physiogeny afterwards make a true recognition of functions

possible, by discovering their historic evolution. Its future promises to be most fruitful. Cf. "Aims and Methods of the Recent History of Evolution" ("Ziele und Wege der Heutigen Entwickelungsgeschichte," pp. 92–98. Jena, 1876).

15 (i. 27). Aristotle. Five books on the generation and evolution of animals (περὶ ζώων γενέσεος).

16 (i. 28). Parthenogenesis. On "virginal generation," or the "immaculate conception" of Invertebrates, especially of Articulated Animals (*Crustacea*, *Insecta*, etc.), see Siebold. "Remarks on Parthenogenesis among Arthropoda" ("Beiträge zur Parthenogenesis der Arthropoden." Leipzig, 1871). Georg Seidlitz, "Parthenogenesis and its Relation to other Forms of Generation in the Animal Kingdom" ("Die Parthenogenesis und ihr Verhältniss zu den übrigen Zeugungs-Arten im Thierreich." Leipzig, 1872).

17 (i. 34). The Preformation-theory. This theory is, in Germany, usually called "Evolutions-theorie," in distinction from the "Epigenesis-theorie." As, however, in England, France, and Italy, the latter is, on the contrary, usually called the theory of evolution, evolution and epigenesis being used as synonymous terms, it appears better to call the former "the theory of preformation." Recently Kölliker has called his "theory of heterogenous generation" "Evolutionism" (note 47). Cf. preface, p xxx.

18 (i. 37). Alfred Kirchhoff, "Caspar Friedrich Wolff, his Life and Teaching in the Science of Organic Evolution."—"Jenaische Zeitschrift für Naturwissenschaft," 1868, vol. iv. p. 193.

19 (i. 43). Part of the writings left by Wolff have not yet been published. His most important works are the dissertation for the degree of doctor, *Theoria generationis* (1759), and his model treatise "de formatione intestinorum" (on the formation of the intestinal canal).—"Nov. Comment. Acad. Sc. Petropol.," xii. 1768; xiii. 1769. Translated into German by Meckel. Halle, 1812.

20 (i. 51). Christian Pander, "*Historia metamorphoseos*, quam

ovum incubatum prioribus quinque diebus subit." Vicebergi, 1817. (Dissertatio inauguralis.) "Contributions toward the history of the evolution of the chick within the egg." ("Beiträge zur Entwickelungsgeschichte des Hühnchens im Eie." Würzburg, 1817.)

21 (i. 52). Karl Ernst Baer, "On the Evolution of Animals. Observations and Reflections" ("Ueber Entwickelungsgeschichte der Thiere. Beobachtung und Reflexion." 2 vols. Königsberg, 1827–1837). In addition to this chief work, cf. "Story of the Life and Writings of Dr. Karl Ernst Baer, told by himself" ("Nachrichten über Leben und Schriften des Dr. Karl Ernst Baer, mitgetheilt von ihm selbst." Petersburg, 1865).

22 (i. 60). Albert Kölliker. His "History of the Evolution of Man and the Higher Animals" ("Entwickelungsgeschichte des Menschen und der höheren Thiere"). The 2nd (corrected) edition, 1876, contains (pp. 28–40) a catalogue of ontogenetic literature. On the newer contributions to this, cf. the "Jahresberichte über die Leistungen und Fortschritte der Medicin" (Berlin), by Virchow and Hirsch (the "History of Evolution," by Waldeyer); also the "Jahresberichte über die Fortschritte der Anatomie und Physiologie," by Hofmann and Schwalbe (Leipzig); the "History of Evolution," by R. Hertwig and Nitsche. Most of Kowalevsky's researches are contained in the "Memoires de l'Académie impériale de St. Petersburg" (from the year 1866). Others are published in Max Schultze's "Archiv für mikroskopische Anatomie," and in other periodicals.

23 (i. 60). Theodor Schwann, "Microscopic Researches into the Identity in Structure and Growth of Plants and Animals" ("Mikroskopische Untersuchungen über die Uebereinstimmung in der Structur und Wachsthum der Thiere und Pflanzen." Berlin, 1839).

24 (i. 69). Ernst Haeckel, the Gastræa Theory, phylogenetic classification of the animal kingdom and homology of the germ-layers.—"Jenaische Zeitschrift für Naturwissenschaft," vol. viii. 1874, pp. 1–56.

25 (i. 75). Ernst Haeckel, "The History of Creation." London, 1876.

26 (i. 81). Fritz Schultze, "Kant and Darwin." A contribution to the history of the science of evolution. Jena, 1875.

27 (i. 81). Immanuel Kant, "Critique of Teleological Reason" ("Kritik der teleologischen Urtheilskraft"). 1790. § 74 and § 79. Cf. also my "History of Creation," vol. i. p. 103.

28 (i. 83). Jean Lamarck, "Philosophie Zoologique, ou Exposition des Considérations relatives à l'histoire naturelle des animaux," etc. 2 Tomes. Paris, 1809. Nouvelle édition, revue et précédée d'une introduction biographique par Charles Martins. Paris, 1873.

29 (i. 88). Wolfgang Goethe on Morphology (zur Morphologie). The formation and re-formation of organic bodies. On Goethe's morphological studies, cf. Oscar Schmidt ("Goethe's Verhältniss zu den organischen Naturwissenschaften." Jena, 1853). Rudolph Virchow, "Goethe as a Naturalist" (Berlin, 1861). Helmholtz, "On Goethe's Natural Scientific Works" (Brunswick, 1865).

30 (i. 96). Charles Darwin. His chief work is "On the Origin of Species by means of Natural Selection" (1859).

31 (i. 99). Darwin and Wallace. The general outlines of the theory of selection were discovered independently by Darwin and Wallace. It does not, however, follow that the services of the latter in furthering the science of evolution are at all comparable with those of the former. As many opponents of Darwin, especially the English Jesuit Mivart, have recently endeavoured to exalt Wallace at the expense of Darwin, and to depreciate the latter, I take this opportunity of expressly asserting that Darwin's services are very far the greater.

32 (i. 101). Thomas Huxley. In addition to the works mentioned in the text, the following popular works are especially to be recommended: "On Our Knowledge of the Causes of Phenomena in Organic Nature," and the "Elementary Physiology" (1871).

33 (i. 101). Gustav Jaeger, "Zoological Letters" ("Zoologische Briefe." Vienna, 1876), and the "Text-book of General Zoology" ("Lehrbuch der Allgemeinen Zoologie." Stuttgart, 1875).

34 (i. 101). Friedrich Rolle, "Man, his Descent and Morality represented in the light of the Darwinian Theory, and on the basis of Recent Geological Discoveries" ("Der Mensch, seine Abstammung und Gesittung im Lichte der Darwin'schen Lehre," etc.). Frankfort, 1866.

35 (i. 102). Ernst Haeckel, "Generelle Morphologie der Organismen." General outlines of the science of organic forms, mechanically shown in accordance with the theory of descent as reformed by Charles Darwin. Vol. i., "General Anatomy;" vol. ii., "General History of Evolution." Berlin, 1866.

36 (i. 103). Charles Darwin, "The Descent of Man, and Selection in Relation to Sex." 2 vols. London, 1871.

37 (i. 108). Karl Gegenbaur, "Outlines of Comparative Anatomy" ("Grundzüge der vergleichenden Anatomie." Leipzig. 2nd ed., 1870). "Elements of Comparative Anatomy" ("Grundriss der vergleichenden Anatomie." 3rd (improved) edition, 1874).

38 (i. 114). Migration-theory. Moritz Wagner, "The Darwinian Theory and the Law of Migration of Organisms" ("Die Darwin'sche Theorie und das Migrations-gesetz der Organismen." Leipzig, 1868). August Weismann, "On the Influence of Isolation in the Formation of Species" ("Ueber den Einfluss der Isolirung auf die Artenbidung." Leipzig, 1871).

39 (i. 116). Carus Sterne, "Evolution and Dissolution" ("Werden und Vergehen"). A popular history of the evolution of nature as a whole. Berlin, 1876. Agassiz a "founder" of natural science. "Gegenwart." Berlin, 1876.

40 (i. 117). Ernst Haeckel, "The Chalk-sponges" ("Die Kalkschwämme; Calcispongien oder Grantien." Berlin, 1872). A monograph and an attempted solution of the problem of the origin of species. Vol. i., "Biology of Chalk-sponges;" vol. ii., "Classification of Chalk-sponges;" vol. iii., "Atlas of Chalk-sponges" (with 60 plates).

41 (i. 124). On the Individuality of Cells and recent reforms in the cell-theory, cf. my "Individualitätslehre," or "Tectologie" ("Generelle Morphologie," vol. i. pp. 239–274). Rudolf Virchow, "Cellular Pathologie." 4th edition. Berlin, 1871.

42 (i. 130). "The Plastid-theory and the Cell-theory."—"Jenaische Zeitschrift für Naturwissenschaft," 1870, vol. v. p. 492.

43 (i. 138). Gegenbaur, "On the Structure and Evolution of Vertebrate Eggs with Partial Yelk-cleavage."—"Archiv f. Anat. u. Phys." 1861, p. 491.

44 (i. 153). Ernst Haeckel, "On Division of Labour in Nature and Human Life," in the collection of Lectures by Virchow-Holtzendorf, 1869. Sect. 78 2nd edition.

45 (i. 160). Monogony (*Generatio neutralis*). On the various forms of asexual reproduction (Schizogony, Sporogony, etc.), cf. "Generelle Morphologie," vol. ii. pp. 36–58.

46 (i. 160). Amphigony (*Generatio sexualis*). On the various forms of sexual reproduction (Hermaphroditism, Gonochorism, etc.), see "Generelle Morphologie," vol. ii. pp. 58–69.

47 (i. 168). Fitful evolution and gradual evolution. The theory of fitful evolution has recently been developed especially by Kölliker, who, under the title of heterogeneous generation, opposes it to gradual evolution as maintained by us ("Zeitschr. f. Wissens. Zool.," vol. xiv. 1864, p. 181, and "Alcyonaria," 1872, pp. 384–415). This theory is distinguished by assuming *entirely unknown causes* for the "fitful evolution of species," a so-called "great law of evolution" (an empty word indeed!). On the contrary, we see, with Darwin, in the facts of Heredity and Adaptation sufficient known (partly inner, partly external) physiological causes, which explain the gradual evolution of species under the influence of the struggle for existence.

48 (i. 170). Immaculate Conception never occurs in the vertebrate tribe. On the other hand, parthenogenesis frequently occurs among Articulated Animals (*Arthropoda*) (note 16).

49 (i. 171). Fertilization of Flowers by insects. Charles Darwin on "The various contrivances by which British and Foreign Orchids are fertilized by Insects." Hermann Müller on "The Fertilization of Flowers by Insects, and the correlative adaptations of both" ("Die Befruchtung der Blumen durch Insecten und die gegenseitigen Anpassungen Beider"). A con-

tribution to our knowledge of causal connection in organic nature. Leipzig, 1873.

50 (i. 178). The Process of Fertilization has been very variously viewed, and was formerly often regarded as an entirely mysterious process, or even as a supernatural miracle. It now appears no more "wonderful or supernatural" than the process of digestion, of muscular movement, or of any other physiological function. For the earlier views, cf. Leuckart, Article "Zeugung" (generation) in R. Wagner's "Dictionary of Physiology," 1850.

51 (i. 179). Monerula. The simple, very transient, kernelless condition, which we briefly call the "monerula," and, in accordance with the fundamental law of Biogeny, regard as a palingenetic reproduction of the phylogenetic Moneron parent-form, appears to vary to some extent in different organisms, especially in the matter of duration. In those cases in which it no longer occurs, and in which the kernel of the fertilized egg persists wholly or partially, we may regard this phenomenon as a later, kenogenetic curtailment of Ontogeny.

52 (i. 181). The Plasson of the monerula appears, morphologically, a homogeneous and structureless substance, like that of the Moneron. This is not contradicted by the fact that we ascribe a very complex molecular structure to the plastidules, or "plasson-molecules," of the monerula; this latter will naturally be more complex in proportion as the organism which it ontogenetically constitutes is higher, and as the ancestral series of that organism is longer, in proportion as the preceding processes of Heredity and Adaptation are more numerous.

53 (i. 182). The Fundamental Significance of the Parent-cell, or cytula, as the foundation-stone of the young organism in the course of development, can only be rightly appreciated, if the part taken in its constitution by the two generating cells is rightly appreciated, the part taken by the male sperm-cell and by the female egg-cell.

54 (i. 183). The One-celled Germ-organism, like the act of fertilization from which it results, has been very variously

viewed. Cf. on this subject, in addition to the four important works, here quoted, by Auerbach, Bütschli, Hertwig, and Strasburger, the most recent annals of the progress of the history of evolution (Waldeyer in Virchow-Hirsch's "Jahresberichten," Berlin; Hertwig in Hofmann-Schwalbe's "Jahresberichten," Leipzig).

55 (i. 185). Protozoa and Metazoa. Cf. vol. i. p. 248; ii. 92. The Protozoa and Metazoa are genetically and anatomically so very distinct, that the former, as Protista, may even be excluded entirely from the animal kingdom, and may be regarded as a neutral intermediate kingdom between the plant and animal kingdoms.—"Generelle Morphologie," vol. i. pp. 191–230. According to this view the Metazoa alone are really animals.

56 (i. 186). The Unity of the Zoogenetic Conception, resulting from the Gastræa-theory, has as yet not been destroyed by the numerous attacks directed against that theory: for none of these attacks have succeeded in substituting anything positive; by pure negation no advance can be made in this dark and difficult subject.

57 (i. 187). The Egg-cleavage and Gastrulation of Man, as represented diagrammatically in Figs. 12–17 of Plate II., is most probably in no essential way different from that of the Rabbit, which has as yet been most closely examined in this point.

58 (i. 188). Ernst Haeckel, "Arabian Corals" ("Arabische Korallen"). "A Journey to the Coral Banks of the Red Sea, and a Glimpse into the Life of Coral Animals. A popular lecture, with scientific explanations." With 5 coloured plates, and 20 woodcuts. Berlin, 1876.

59 (i. 189). The Number of the Segmentella, or cleavage-cells, increases, in the original, pure forms of palingenetic egg-cleavage, in regular geometric progression. But the point to which this proceeds varies in the various archiblastic animals, so that the Morula, as the final result of the cleavage-process, consists sometimes of 32, sometimes of 64, sometimes of 128 cells, and so on.

60 (i. 189). The Mulberry-germ, or Morula. The seg-

mentellæ, or cleavage-cells, which constitute the Morula at the close of palingenetic egg-cleavage, generally appear entirely similar, with morphological difference in size, form, or constitution. This does not, however, hinder the fact that these cells have separated, even during cleavage, into animal and vegetable cells, have differentiated physiologically, as is indicated in Figs. 2 and 3, Plate II., as probable.

61 (i. 189). The Bladder-germ of Archiblastic Animals (*blastula*, or *blastosphæra*), which is now commonly known as the germ-vesicle, or, more accurately, as the "germ-membrane vesicle," must not be confused with the essentially different "germ-vesicle" of amphiblastic mammals, which is better called the "intestinal-germ vesicle" (*gastrocystis*). The gastrocystis and the blastula are still often united under the name of "germ-vesicle, or *vesicula blastodermica*." Cf. vol. i. p. 290.

62 (i. 192). The Definition of the Gastrula was first established by me in 1872, in my "Monograph of Chalk-sponges" (vol. i. pp. 333, 345, 466). There I already gave due weight to the "extremely great significance of the gastrula in reference to the general Phylogeny of the animal kingdom" (p. 333). "The fact that these larval forms re-occur in the most different animals, cannot, I think, be sufficiently estimated, and bears plain witness to the former common descent of all from the Gastræa" (p. 345).

63 (i. 194). The Uniaxial Outline of the Gastrula is, on account of the two different poles of the axis, more accurately described as a diplopolic uniaxial form (a sternometric outline: conoid-form, or cone). Cf. my "Promorphology" ("Generelle Morphologie," vol. i. p. 426).

64 (i. 194). Primitive Intestine and Primitive Mouth. My distinction of the primitive intestine and primitive mouth (*protogaster* and *protostoma*) from the later, permanent intestine and mouth (*metagaster* and *metastoma*) has been variously attacked; it is, however, as much justified as the distinction of the primitive kidney from the permanent kidney, of the primitive vertebræ from the permanent vertebræ. The primitive intestine

forms but a part of the permanent intestine, and the primitive mouth (at least in the higher animals) does not become the permanent mouth.

65 (i. 196). Primitive germ-layers (*blastophylla*). As the two primary germ-layers (*entoderma* and *exoderma*) originally form the sole histogenetic rudiment of the whole body, and as the *mesoderma*, the nutritive yelk, and all other accessory parts of the germ have developed only secondarily from the former, I consider it very important to distinguish between the primary and secondary germ-layers. The latter, to distinguish them from the former, might be called "**after** germ-layers" (*blastelasma*).

66 (i. 201). Unequal Cleavage and Hood-gastrula (*Segmentatio inæqualis* et *Amphigastrula*). Next to Amphibia the most accessible examples for observation of unequal cleavage and the Amphigastrula are afforded by the indigenous Soft-bodied Animals (*Mollusca*) and Worms (Snails and Mussels, Earth Worms and Leeches).

67 (i. 202). The Colour of Amphibian-eggs is occasioned by the accumulation of dark colouring-matter at the animal pole of the egg. In consequence of this the animal-cells of the exoderm appear darker than the vegetative cells of the entoderm. In most animals the reverse is the case; the protoplasm of the entoderm cells being usually darker and more coarsely granulated (vol. i. p. 197).

68 (i. 207). Hood-gastrula of Amphibia. Cf. Robert Remak, "On the Evolution of Batrachia" ("Ueber die Entwickelung der Batrachier," p. 126; Plate XII. Figs. 3–7). Stricker's "Manual of Tissues" ("Handbuch der Gewebelehre," vol. ii. p. 1195–1202; Figs. 399–402). Goette, "History of the Evolution of *Bombinator*" ("Entwickelungsgeschichte der Unke," p. 145; Plate II. Figs. 32–35).

69 (i. 214). Hood-gastrula of Mammals. Eduard van Beneden, "La maturation de l'œuf, la fécondation et les premières phases du développement embryonnaire des Mammifères, d'après des recherches faites chez le lapin." Brussels, 1875. No figures

are given with these "Communication préliminaire;" Van Beneden's description is, however, so clear, so thorough and careful, that they afford an entirely satisfactory insight into unequal egg-cleavage and the formation of the Hood-gastrula in Mammals. All other observers, who have studied the germination of Mammalian eggs (among the most recent Kölliker, Rauber, and Hewson may be especially mentioned), have overlooked or failed to recognize the important features discovered by Van Beneden.

70 (i. 218). The Disc-gastrula (*Disco-gastrula*) of Osseous Fishes (*Teleostei*). Van Bambeke, "Recherches sur l'embryologie des poissons osseux." Brussels, 1875. The transparent Fish-eggs, in which I observed discoid cleavage (*Segmentatio discoidalis*) and the formation of the Disc-gastrula by invagination, are accurately described in my article on "The Gastrula and Egg-cleavage of Animals" ("Jen. Zeitschrift für Naturwissenschaft," 1875, vol. ix. p. 432–444; Plates IV., V.). On the Disc-gastrula of *Selachii*, cf. Balfour, "The Development of Elasmo branch Fishes."—"Journ. of Anat. and Physiol.," vol. x. p. 517; Plates XX., XXIII.

71 (i. 221). Yelk-cells of Birds. The cell-like constituent parts, which occur in great number and variety in the nutritive yelk of Birds and Reptiles, as in most Fishes, are nothing less than true cells, as His and others have asserted. This does not mean that in this matter a distinct limit everywhere exists between the nutritive and the formative yelks, as in our oceanic Fish-eggs (Figs. 42, 43, note 70). On the contrary, *originally* (phylogenetically) the nutritive yelk originated from part of the entoderm.

72 (i. 223). Egg-cells of Birds. Notwithstanding the large nutritive yelk, the "after-egg" (*metovum*) of Birds and Reptiles is, in form-value, a single cell. The very small, active protoplasm of the "tread" does, however, indeed fall far short, in volume, of the huge mass of the yellow yelk-ball. The bird's eggs are absolutely the largest cells of the animal body. Cf. note 43, and Eduard van Beneden, "Recherches sur la composition et la

signification de l'œuf." Brussels, 1870. Hubert Ludwig, "On Egg-structure in the Animal Kingdom" ("Ueber die Eibildung in Thierreiche." Würzburg, 1874).

73 (i. 226). Discoidal cleavage (*Segmentatio discoidalis*) of Bird's eggs. Cf. Kölliker, "History of the Evolution of Man and the Higher Animals" ("Entwickelungsgeschichte des Menschen und der höheren Thiere." 2nd edition, 1876, pp. 69–81; Figs. 16–22).

74 (i. 227). Disc-gastrula (*Disco-gastrula*) of Birds. Cf. Rauber, "On the Place of the Chick in the System of Evolution" ("Ueber die Stellung des Hühnchens im Entwickelungsplan"). Leipzig, 1876. Foster and Balfour, "The Elements of Embryology." London, 1874.

75 (i. 231). Bladder-gastrula (*Perigastrula*) of Articulated Animals (*Arthropoda*). Cf. Bobretzky, "Russian Essay on the Germ-history of Astacus and Palæmon." Kiew, 1873. Also my own article on the gastrula and egg-cleavage.—"Jen. Zeitschrift für Naturwissenschaft." Vol. ix. pp. 444–452, Plate VI.

76 (i. 234). The Four-layer Theory, which was first clearly stated by Baer in 1837 ("Entwickelungsgeschichte der Thiere," vol. ii. pp. 46, 68), and which we have here carried out logically, yet appears the only form of the germ-layer theory, which, on comparative observation of all higher animals, supplies a universal law of germination for all and at the same time meets the inconsistent reputations of many observers.

77 (i. 239). Caspar Friedrich Wolff first indicated the Four-layer Theory (note 76). Cf. the remarkable sentence, quoted at vol. i. p. 45, from his pregnant work on the formation of the intestinal canal (note 19).

78 (i. 240). The Four Main Types of Gastrulation, which are diagrammatically distinguished in Plates II. and III., and in Tables III. and IV. (vol. i. pp. 241, 242), are of course connected by intermediate forms. These are transitions both between the primordial and the unequal forms, and between the primordial and the superficial forms; similarly, the unequal form of egg-cleavage is connected by twixt-forms with the discoidal forms, which latter

is again, perhaps, connected in the same way with the superficial form.

79 (i. 241). The Gastrulation of the various classes of animals has been far too little studied to enable us thoroughly to summarize the distribution of the various forms within the separate classes. Yet it is already evident that primordial egg-cleavage and the formation of the Archigastrula occur in the lowest classes of each tribe.

80 (i. 243). The Rhythm of egg-cleavage is by no means as regular as might appear from the four first examples in the five tables. There are, on the contrary, many variations, and not infrequently an entirely irregular and very variable sequence of numbers occurs (especially in discoided cleavage).

81 (i. 246). Definition of the Type. Cf. Gegenbaur, "Elements of Comparative Anatomy," 1874, p. 59.

82 (i. 246). Types and Phyla. According to the prevailing "Type-theory," the types of the animal kingdom are *parallel*, and entirely independent; according to my "Gastræa-theory," on the contrary, they are divergent tribes, connected at the roots; according to the view of Claus and other opponents, the latter is no essential distinction.

83 (i. 248). The one-celled condition of Infusoria entirely forbids their morphological comparison with Metazoa. Cf. my article "On the Morphology of Infusoria" ("Jen. Zeitschrift für Naturwissenschaft" 1873, vol. vii. p. 516–568).

84 (i. 257). The axes of the Vertebrate outline. Cf. my "Promorphology" (Stereometry of Organisms).—"Generelle Morphologie," vol. i. pp. 374–574. "Singly double-outlines" (*Dipleura*), p. 519. "Bilateral-symmetrical" forms in the fourth signification of the word.

85 (i. 255). The Primitive Vertebrate Type, as it is represented in Figs. 52–56, is a hypothetic diagram, which is principally founded on the outline of the Amphioxus, but in which the Comparative Anatomy of Ascidia and Appendicularia on the one side, of Cyclostomi and Selachii on the other, is regarded. This diagram is by no means meant to be an "exact figure," but

a provisional stage in the hypothetic reconstruction of the unknown, long extinct parent-form of Vertebrates, an "Archi-type."

86 (i. 258). Only very uncertain assumptions can be made as to the sense-organs of the hypothetic parent-form, for these organs, more than any others, have been subject to adaptations, and in Ascidia, as in the Amphioxus, have probably been much atrophied. The earliest Vertebrates probably inherited a pair of eyes of very simple character and a pair of simple ear-vesicles from Worms.

87 (i. 267). The primitive kidneys were perhaps already metameric in the hypothetic parent-form of Vertebrates, so that in addition to the two longitudinal main canals (primitive kidney ducts) numerous transverse tubes (segmental canals) were connected with these main canals, a pair in each metameron of the middle part of the body. Perhaps these already opened through ciliated funnels into the body-cavity (*cœloma*), as is now the case in Annelids, and, according to Balfour, in the embryos of Selachii. Cf. Balfour, "Development of Elasmobranch Fishes."—"Quarterly Journal of Microscopical Science." New Series, vol. xiv. p. 323; "Journal of Anat. and Physiol." vol. x.

88 (i. 273). The germination of Primitive Vertebrates. Cf. with Table VI., Table VII. (vol. i. p. 327), Table XI. (p. 467); also the diagrammatic figures in Plates IV. and V. with explanation (p. 321).

89 (i. 276). The Germ-forms of the earliest Vertebrates, as they are represented in diagrammatic cross sections in Figs. 62–69, can only, of course, be approximately guessed, and with the aid of Comparative Anatomy and Ontogeny. These hypothetic diagrams, therefore, by no means claim to be accepted dogmatically, any more than do those in Figs. 52–56. (Cf. note 85.)

90 (i. 280). Main incidents in Vertebrate germination. Of the main palingenetic incidents here enumerated, perhaps the sixth, ninth, and tenth originally occurred in a very dif-

ferent form. The other seven now appear to be pretty well established.

91 (i. 285). The flat germ-disc of Birds, which even now, in the opinion of most embryologists, represents the first starting-point in the formation of the embryo, and to which all other germ-forms have been referred, is, on the contrary, a late and much modified germ-form, which has arisen in consequence of the extension of the gastrula over the greatly enlarging nutritive yelk.

92 (i. 289). Site of Fertilization. In Man, as in other Mammals, fertilization of the eggs probably usually takes place in the oviduct: here, the eggs which, at the rupture of the Graafian follicles, have emerged from the female ovary and passed into the outer opening of the oviduct, meet with the active sperm-cells of the male seed, which, during copulation, penetrated into the uterus, and from there passed into the inner opening of the oviduct. Rarely, fertilization occurs even on the ovary, or not till within the uterus. (Cf. Chapter XXV.)

93 (i. 293). The origin of the mesoderm in Mammals, as in other animals, is, at present, among the most obscure and contested points of Ontogeny. Remak, Balfour, and others derive it from the entoderm, Kölliker and others from the exoderm. Waldeyer, His, and others assert that both primary germ-layers take part in the formation of the mesoderm. The last assumption is, I believe, correct. (Cf. notes 76, 77.)

94 (i. 297). The Germ-shield (*Notaspis*). The ordinary view, that the germ-shield (= Remak's "Doppelschild") is the earliest rudiment of the actual embryo, results in many erroneous conclusions. It is, therefore, necessary to point out especially that the germ-shield represents the first well-defined central dorsal part of the embryo.

95 (i. 317). Body Wall and Intestinal Wall. The morphological distinction between the body wall and the intestinal wall, certainly primordial, is probably referable to the simple primary germ-layers of the Gastræa. If the skin-fibrous layer is derived from the exoderm, and the intestinal-fibrous layer from the

entoderm, this most simply explains the progressive development of this distinction, which may be traced through the series of Worms, and up to Vertebrates.

96 (i. 320). Palingenetic and Kenogenetic germination. In the germ-history of Vertebrates no clear conception of the embryological process has yet been attained, because all authors have started from the higher Vertebrates (usually from the Chick) and have assumed that the form of evolution occurring in this case is original and typical. It is only since the germ-history of the Amphioxus has taught us the palingenetic, really original form of germination of Vertebrate organisms, that we have been enabled, by Comparative Ontogeny (and especially by the principles of the Gastræa theory), rightly to understand and to explain phylogenetically the kenogenetic forms of germination of higher Vertebrates.

97 (i. 321). The Diagrams in Plates IV. and V. are as simple and abstract as possible, in order to render the desired general explanation as easy as possible.

98 (i. 346). Primitive Vertebræ and Metamera. For the right conception of "primitive vertebral" structure it is especially necessary to point out that the primitive vertebræ are much more than their name indicates. They must, in fact, be conceived as individual, consecutive sections of the trunk, which have arisen one after the other, as true "metamera," or consecutive pieces ("Generelle Morphologie," vol. i. p. 312). Each primitive vertebra of a Vertebrate, like each trunk-segment or metameron of an Annelid or Arthropod, contains all the essential, morphological constituent parts, characteristic of the corresponding animal-tribe.

99 (i. 349). Origin of the Primitive Vertebræ. My conception of these as individual, morphological "consecutive pieces," which, like the metamera of Cestods and Annelids, have arisen by terminal budding from a single unarticulated piece, has been much attacked. I therefore emphatically remark that I only understand this process in the widest sense. In both cases there is certainly a reproduction of individual, like parts, which have originated (in time and space) consecutively.

100 (i. 361). The agreement among the germ-forms of various Mammals is instructive especially because it shows us how, by diversity in the mode of evolution, the most diverse structures can originate from one and the same form. As we actually see this in germ-forms, we may hypothetically assume the same to have occurred among tribe-forms. Moreover, this agreement is never absolute identity, but always only the very greatest similarity. Even the germs of the various individuals of a species are never actually identical.

101 (i. 366). The law of the ontogenetic connection of systematically allied animal-forms has many apparent exceptions. These are, however, fully explained by the adaptation of the germ to kenogenetic conditions of existence. Where the palingenetic form of evolution of the germ has been accurately transmitted by heredity, that law is always in force. Cf. Fritz Müller, "Für Darwin" (note 111).

102 (i. 367). Earliest human germs. Cf. Kölliker, "History of the Evolution of Man" ("Entwickelungsgeschichte des Menschen." 2nd edition, 1876, pp. 303–319). Also Ecker, "Icones physiologicæ." Leipzig, 1859. Plates XXV.–XXXI. The earliest human germs which have yet been certainly recognized, were from twelve to fourteen days old, and were observed by Prof. Allen Thomson, of Glasgow. No opportunity has ever occurred for the observation of earlier germs.

103 (i. 369). Human germs of three weeks (twenty to twenty-one days) exhibit in their whole structure that phylogenetic stage of evolution which, among extant Vertebrates, is represented by the Cyclostomi (Lampreys and Hags, vol. ii. p. 103), and which must be referable to extinct Monorhine ancestors of similar structure.

104 (i. 370). Human germs of four weeks (twenty-five to thirty days), on the whole, exhibit in their whole structure that phylogenetic stage of evolution, which is exhibited in Sharks and Rays, among extant Vertebrates, and which is referable to similar extinct Primitive Fish ancestors (*Proselachii*). Of course this comparison is affected by various kenogenetic modifications

(both heterotopic and heterochronic), just as in the former. (Cf. note 108.)

105 (i. 374). The nose of Nosed-apes is much more different from that of other Apes than from that of Man. Moreover, even the extreme variety and variability in the external form of the human nose shows how small is the morphological value of this organ, so important to the physiognomy.

106 (i. 383). The bladder-like form of the human Allantois. Cf. W. Krause, "On the Allantois in Man" ("Ueber die Allantois des Menschen."—"Archiv für Anat. u. Physiol.," 1875, p. 215, Plate VI.).

107 (i. 400). The navel-cord (*funiculus umbilicalis*), like the placenta, is an organ shared by Man exclusively with Placental Animals. Cf. Chap. XIX. pp. 155–168, and Figs. 200, 201. On the more minute structure of this organ, and on the special features of the embryonic blood-circulation, cf. Kölliker, "History of the Evolution of Man." 2nd edition, 1876, pp. 319–363.

108 (i. 401). The Kenogeny of Man. In pointing out the phylogenetic significance of the separate incidents and periods of human germ-history, and in explaining them by reference to corresponding processes and stages in the tribal history of our animal ancestors, we must always bear in mind that in Man, as in all higher animals, the original palingenetic cause of germination has undergone much kenogenetic modification in consequence of many adaptations to the very various conditions of embryonic life, that it has thus been much violated and contracted. The higher the organism develops, the more are especially these earliest stages of evolution abbreviated.

109 (i. 404). The sections of human germ-history, of which only four larger and ten smaller are mentioned here in reference to their phylogenetic significance, allow of much more division if their comparative Ontogeny is minutely examined. This phylogenetic significance may also be very well explained with fitting reference to kenogenetic displacements in place and time (vol. i. p. 13).

110 (i. 405). Figures of human embryos in all stages of

germ-history were given in very beautiful detail by M. P. Erdl thirty years ago: "The Evolution of Man, and of the Chick in the Egg" ("Die Entwickelung des Menschen, und des Hühnchens im Ei." Leipzig, 1845).

111 (i. 409). Fritz Müller, "Für Darwin." Leipzig, 1864. A very excellent little book, in which the modification of the fundamental law of Biogeny (with reference to the Phylogeny of Crustacea) are explained for the first time.

112 (i. 413). The Method of Phylogeny is of the same morphological value as the well-known method of Geology, and may, therefore, claim exactly the same scientific acceptation. Cf. the excellent discourse by Eduard Strasburger, "On the Importance of Phylogenetic Methods in the Study of Living Beings."—"Jenaische Zeitschrift für Naturwissenschaft," 1874, vol. viii. p. 56.

113 (i. 415). Johannes Müller, "On the Structure and Vital Phenomena of *Amphioxus lanceolatus*."—Transactions of the Berlin Academy, 1844.

114 (i. 415). Recent works on the Amphioxus. W. Rolph and E. Ray Lankester especially have recently added to our knowledge of the organology of the Amphioxus, Wilhelm Müller and P. Langerhans to that of its histology. The literature of this subject is fully represented by W. Rolph, in his "Researches into the Structure of the Amphioxus" ("Untersuchungen über den Bau des Amphioxus."—"Morpholog. Jahrb.," vol. ii. p. 87, Plates V. and VII.), and in P. Langerhans, "On the Anatomy of the Amphioxus" ("Zur Anatomie des Amphioxus."—"Archiv. für Mikr. Anat.," vol. xii. p. 290, Plates XII.–XV.).

115 (i. 416). Acrania and Craniota. The separation of Vertebrates into Skull-less Animals (*Acrania*) and Skulled Animals (*Craniota*), which I first indicated in 1866 in my "Generelle Morphologie," appears to me absolutely essential for the phylogenetic explanation of the Vertebrate-tribe.

116 (i. 428). Max Schultze, "History of the Evolution of Petromyzon" ("Entwickelungsgeschichte von *Petromyzon*." Haarlem, 1856). The Ontogeny of the Hags, which promises very important results, is yet, unfortunately, entirely unknown.

117 (i. 430). Savigny, "Mémoires sur les Animaux sans Vertébres." Vol. ii., Ascidies, 1816. Giard, "Recherches sur les Synascidies."—"Archives de Zoologie Experimentale," vol. i., 1872.

118 (i. 435). Syn-ascidia and Echinoderms. The Corm-theory of Echinoderms, which I explained in 1866 ("Generelle Morphologie," vol. ii. p. lxiii), and which has been much attacked as "paradoxical," is as yet the sole theory attempting the genetic explanation of this remarkable group of animals.

119 (i. 442). Kowalevsky, "History of the Evolution of the Amphioxus and of Simple Ascidians" ("Mémoires de l'Acad. de S. Petersbourg." 7 Serie. Tom. x. and xi. 1867–8).

120 (i. 450). The metameric structure of the Amphioxus which is indicated in its nerve and muscle systems, undoubtedly shows that the notochord exists in Vertebrates previous to their metameric structure, and consequently that it is inherited from unarticulated Chorda Animals.

121 (i. 454). The Metamorphosis of the Amphioxus, through which the larva passes into the adult form, is not yet fully known in all its details. This does not, however, affect the extraordinarily important bearing of the thoroughly known, earliest incidents in its germination on the palingenesis of Vertebrates.

122 (i. 455). Fertilization of Ascidia (*Phallusia mammillata*), Eduard Strasburger, "On Cell-structure and Cell-division, with Studies of Fertilization." 2nd edition. Jena, 1876, p. 306, Plate VIII.

123 (i. 462). Kupffer. The tribal relation of Ascidia to Vertebrates ("Archiv für Mikros. Anat.," 1870, vol. vi. pp. 115–170). Oscar Hertwig, "Researches into the Structure and Evolution of the Cellulose Mantles of Tunicata" ("Untersuchungen über den Bau und die Entwickelung des Cellulose-Mantels der Tunicaten"). Richard Hertwig, "Contribution to Knowledge of Ascidian Structure" ("Beiträge zur Kenntniss des Baues der Ascidien."—"Jenaische Zeitschrift für Naturwissenschaft," 1873, vol. vii.).

124 (i. 464). The Phylogenetic Importance of the Amphioxus cannot be too highly insisted on. Without knowledge of its Anatomy and Ontogeny, the origin of Vertebrates would be entirely dubious, and their descent from Worms would appear incredible.

125 (i. 467). The Ontogenetic Cell-pedigree, as it is represented, with reference to the Amphioxus, in Table XI., probably holds good, in its most important features, for all Vertebrates, and, therefore, also for Man. For, more than any other form, the Amphioxus by strict Heredity has accurately retained its Palingenesis. This histogenetic cell-pedigree is apparently well established as regards most and the chief features; on the other hand, it yet appears doubtful with regard to the origin of the primitive kidneys, the testes, and ovaries.

126 (ii. 4). Milne-Edwards, "Leçons sur la Physiologie Comparée," vol. ix.

127 (ii. 6). Eternity of Organic Life. According to the monistic view, organic life is a further form of evolution of the inorganic word-processes, and had a beginning in time on our planet. In opposition to this, A. Fechner, among others, in his "Thoughts on the Creation and Evolution of Organisms," has stated certain opposed "kosmorganic phantasys" which appear entirely irreconcilable with the ontogenetic facts given here.

128 (ii. 18). Bernhard Cotta ("Geologie der Gegenwart," 1866; 4th edition, 1874) and Karl Zittel ("Aus der Urzeit;" München, 1875, 2nd edition) have made some excellent remarks on the duration and the whole course of the organic history of the world.

129 (ii. 21). August Schleicher, "The Darwinian Theory and Philology" ("Die Darwin'sche Theorie und die Sprachwissenschaft." Weimar, 1863. 2nd edition, 1873).

130 (ii. 25). At first sight, most polyphyletic hypotheses appear more simple and easy than do monophyletic, but the former always present more difficulties the more they are considered.

131 (ii. 25). Those physiologists who desire an experi-

mental proof of the theory of descent, merely thereby prove their extraordinary ignorance of the morphological scientific facts relating to this matter.

132 (ii. 30). Spontaneous generation.—"Generelle Morphologie," vol. i. pp. 167–190. "Monera and Spontaneous Generation."—"Jenaische Zeitschrift für Naturwissenschaft," 1871, vol. vi. pp. 37–42.

133 (ii. 33). The Absence of Organs in Monera. In saying that Monera are "organisms without organs," we understand the definition of organs in a morphological sense. In a physiological sense, on the other hand, we may call the variable plasson-processes of the body of the Moneron the "*pseudopodia*" organs.

134 (ii. 36). Induction and Deduction in Anthropogeny. "Generelle Morphologie," vol. i. pp. 79–88; vol. ii. p. 427. "History of Creation," vol. ii. p. 357.

135 (ii. 42). Animal Ancestors of Man. The number of species (or, more accurately, form-stages, which are distinguished as "species") must, in the human ancestral line (in the course of many millions of years!), have amounted to many thousands; the number of genera to many hundreds.

136 (ii. 47). Following Elsberg, we give the name of "plastidules" to the "molecules of plasson," to the smallest like parts of that albuminous substance which, according to the "plastid-theory," is the material substratum of all the active phenomena of life. Cf. my work on "The Perigenesis of Plastidules" ("Perigenesis der Plastidule oder Wellenzeugung der Lebenstheilchen." Berlin, 1876). This is an attempt to explain mechanically the elementary processes of evolution.

137 (ii. 49). Bathybius and the free protoplasm of ocean depths. Cf. my "Studies on Monera and other Protista." Leipzig, 1870, p. 86. The most recent observations on living Bathybius are those of Dr. Emil Bessel, who found this form on the coast of Greenland (in Smith's Sound), at a depth of about 550 ft. He noticed very active amœboid movements in them, as well as the assumption of foreign particles (carmine, etc.). "It consists of nearly pure protoplasm, tinged most intensely by

a solution of carmine in ammonia. It contains fine gray granules of considerable refracting power, and besides the latter a great number of oleaginous drops, soluble in ether. It manifests very marked amœboid motions, and takes up particles of carmine, etc." —Packard, "Life Histories of Animals, including Man." New York, 1876.

138 (ii. 50). The Philosophical Importance of Monera in explaining the most obscure biological questions cannot be sufficiently emphasized. Monograph of Monera.—"Jenaische Zeitschrift für Naturwissenschaft," vol. iv., 1868, p. 64.

139 (ii. 54). The Nature and Significance of the Egg-cell can only be philosophically understood by means of phylogenetic examination.

140 (ii. 58). Synamœba. Cienkowski, "On the Structure and Evolution of Labyrinthula" ("Uber den Bau und die Entwickelung der Labyrinthuleen."—Arch. für Mikrosk. Anat., 1870, vol. iii. p. 274). Hertwig, "Microgromia Socialis."—*Ibid.*

141 (ii. 61). Catallacta, a new Protista-group (*Magosphæra planula*). See "Jenaische Zeitschrift für Naturwissenschaft," vol. vi., 1871, p. 1.

142 (ii. 66). Haliphysema and Gastrophysema. Extant Gastræads. See "Jenaische Zeitschrift für Naturwissenschaft," vol. xi., 1876, p. 1, Plates I.–VI.

143 (ii. 70). The five first stages in the evolution of the animal body, which are compared in Table XVII., and which are common to Man and all higher Animals, are established beyond all doubt as existing in the Ontogeny of most extant animals. As Comparative Anatomy shows that corresponding form-stages yet exist in the system of the lower animals, we may assume, in accordance with the fundamental law of Biogeny, that similar forms existed phylogenetically as most important ancestral forms.

144 (ii. 77). On the distinction of the axes, and on the geometric outline of the animal body, see "*Promorphologie*" ("Generelle Morphologie," vol. i. pp. 374–574).

145 (ii. 87). The hermaphrodite structure of our ancestral

series was perhaps transmitted from the Chorda Animals even as far as the lower stages of Vertebrate ancestors. Cf. Chapter XXV.

146 (ii. 89). I am inclined to regard the Appendicularia as living Chorda Animals of the present day; they are the only Invertebrates permanently possessing a notochord, and thus, as by many other peculiarities, distinguished from genuine Tunicates.

147 (ii. 105). Metamorphosis of Lampreys. That the blind Ammocœtes change into Petromyzon was known two hundred years ago (1666) to the fisherman Leonhard Baldner of Strasburg; but this observation remained unrecognized, and the modification was first discovered by August Müller in 1854 ("Archiv für Anat.," 1856, p. 325). Cf. Siebold, "The Fresh-water Fishes of Central Europe" ("Die Süsswasserfische von Mittel-Europa," 1863).

148 (ii. 114). Selachii as Primitive Fishes. The old disputes as to the systematic position and kindred of Selachii were first definitely settled by Gegenbaur, in the introduction to his classical work on "The Head-skeleton of Selachii."

149 (ii. 118). Gerard Krefft, "Description of a Gigantic Amphibian;" and Albert Günther, "Ceratodus, and its Systematic Position."—"Archiv für Naturgeschichte," 37, 1871, vol. i. p. 321; also "Phil. Trans.," 1871, Part II. p. 511, etc.

150 (ii. 129). The duration of metamorphosis of Amphibia varies much in the different forms of Frogs and Toads, the whole forming a complete phylogenetic series from the original, quite complete form, to the later, much shortened and vitiated heredity of modification.

151 (ii. 129). "All the histological features of the Land Salamander (*Salamandra maculata*) force the impression that it belongs to an entirely different epoch of terrestrial life than that of the Water Salamander (*Triton*), externally so similar."—Robert Remak ("Entwickelung der Wirbelthiere," p. 117).

152 (ii. 130). Siredon and Amblystoma. Very various views have lately been expressed as to the phylogenetic significance to be attributed to the much-discussed modification of the Mexican

Axolotl into an Amblystoma. Cf. on this subject especially August Weismann, in "Zeitsch. für wissensch. Zoologie," vol. xxv., Sup., pp. 297–334.

153 (ii. 131). The Leaf-frog of Martinique (*Hylodes martinicensis*) loses its gills on the seventh day, its tail and yelk-sac on the eighth day of egg-life. On the ninth or tenth day after fertilization the complete frog emerges from the egg.—Bavay, "Sur l'Hylodes Martinicensis et ses Metamorphoses." "Journal. de Zool. par Grevais," vol. ii. 1873, p. 13.

154 (ii. 133). "Homo diluvii testis" = Andrias Scheuchzeri. "Sad bone of an ancient evil-doer; Soften, stone, the heart of the new children of evil" (Diaconus Miller). Quenstedt. "Formerly and Now" ("Sonst und Jetzt," 1856, p. 239).

155 (ii. 133). The Amnion-structure of the three higher Vertebrate-classes, wanting in all lower Vertebrates, has *no* connection with the similar, but independently acquired Amnion-structure (analogous, but *not* homologous) of higher Articulated Animals (*Arthropoda*).

156 (ii. 138). The former existence of a Protamnion, the common parent-form of all Amniota, is undoubtedly shown by the Comparative Anatomy and Ontogeny of Reptiles, Birds, and Mammals. No fossil remains of such a Protamnion have, however, yet been discovered. They must be sought in the Permian or Carboniferous formation.

157 (ii. 147). The former organisation of the Promammalia may be hypothetically reconstructed from the Comparative Anatomy of the Salamander, Lizards, and Beaked Animals (*Ornithorhynchus*).

158 (ii. 153). The Didelphic ancestors of Man may have been externally very different from all known Pouched Animals (*Marsupialia*), but possessed all the essential internal characters of Marsupialia.

159 (ii. 163). The phylogenetic of the Semi-apes, as the primæval placental parent-group, is not influenced by our ignorance of any fossil Prosimiæ, for it is never safe to estimate palæontological facts as *negative*, but only as *positive*.

160 (ii. 168). On the structure of the Decidua very various theories have been given. Cf. Kölliker, "History of the Evolution of Man" ("Entwickelungsgeschichte des Menschen." 2nd edition, 1871, pp. 319–376). Ercolani (Giambattista), "Sul processo formativo della placenta." Bologna, 1870. "Le glandole otricolari del'utero." Bologna, 1868, 1873. Huxley, "Lectures on the Elements of Comparative Anatomy," 1864, pp. 101–112.

161 (ii. 172). Huxley, "Anatomy of Vertebrates," 1873, p. 382. Previously Huxley had separated the "Primates" into seven families of nearly equal systematic value. (See "Man's Place," etc., p. 119.)

162 (ii. 179). Darwin. Sexual selection in Apes and Man.—"Descent of Man," vol. ii. pp. 210–355.

163 (ii. 180). Man-like Holy Apes. Of all Apes, some Holy Apes (*Semnopithecus*) most resemble Man, in the form of their nose and the character of their hair (both that on the head and that on the beard).—Darwin, "Descent of Man," vol. i. p. 335; vol. ii. p. 172.

164 (ii. 182). Friedrich Müller ("Allgemeine Ethnographie." Vienna, 1873, p. 29), on the supposed age of man. Families of languages (pp. 5, 15, etc.).

165 (ii. 185). The plate (XV.) representing the migrations, given in the "History of Creation," merely claims the value of a first attempt, is an hypothetic sketch, as I there expressly said, and as, in consequence of repeated attacks, I must here insist.

166 (ii. 201). The Leather-plate. The phylogenetic distinction of a special leather-plate, the outermost lamella separating from the skin-fibrous layer, is justified by Comparative Anatomy.

167 (ii. 204). Milk-glands. Huss, "Contributions to the History of the Evolution of the Milk-glands" ("Beiträge zur Entwickelungsgeschichte der Milchdrüsen"); and Gegenbaur, "On the Milk-gland Papillæ" ("Jenaische Zeitschrift für Naturwissenschaft," 1873, vol. vii. pp. 176, 204).

168 (ii. 208). On the hairy covering of Man and Apes, see Darwin, "Descent of Man," vol. i. pp. 20, 167, 180; vol. ii. pp. 280, 298, 335, etc.

169 (ii. 217). Dorsal side and ventral sides are homologous in Vertebrates, Articulated Animals (*Arthropoda*), Soft-bodied Animals (*Mollusca*), and Worms, so that the dorsal marrow and the ventral marrow are not comparable. Cf. Gegenbaur, "Morph. Jahrbuch," vol. i. pp. 5, 6.

170 (ii. 228). The unknown ontogenetic origin of the sympathetic nerve-system must probably, for phylogenetic reasons, be sought chiefly in the intestinal layer, *not* in the skin-layer.

171 (ii. 248). On the cavities connected with the nose, see Gegenbaur, "Elements of Comparative Anatomy," p. 580.

172 (ii. 260). The analogies in the germination of the higher sense organs were rightly grasped even by the earlier natural philosophers. The first more accurate sketches of the very obscure germ-history of the sense-organs, especially of the eye and ear, were given (1830) by Emil Huschke, of Jena (Isis, Meckel's Archiv, etc.).

173 (ii. 265). Hasse, "Anatomical Studies" ("Anatomische Studien"), chiefly of the organ of hearing. Leipzig, 1873.

174 (ii. 269). Johannes Rathke, "On the Gill-apparatus and the Tongue-bone" ("Ueber den Kiemen-apparat und des Zungenbein," 1832). Gegenbaur, "On the Head-skeleton of Selachii," 1872. (See note 124.)

175 (ii. 272). On the Rudimentary Ear-shell of Man, cf. Darwin, "Descent of Man," vol. i. pp. 17–19.

176 (ii. 276). Scarcely anywhere does Comparative Anatomy prove its high morphological value as with reference to the skeleton of Vertebrates: in this matter it accomplishes much more than Ontogény. There is all the more reason to insist on this here, as Goette, in his gigantic history of the evolution of Bombinator, has recently denied all scientific value to Comparative Anatomy, and asserted that Morphology is explained solely by Ontogeny. Cf. my "Aims and Methods of the Recent History of Evolution" ("Ziele und Wege der heutigen Entwickelungsgeschichte," 1875, p. 52, etc.).

177 (ii. 283). The Human Tail, like all other rudimentary organs, is very variable in point of size and development. In

rare cases it remains permanently, projecting freely: usually it disappears at an early period, as in Anthropoid Apes.

178 (ii. 284). On the Number of Vertebræ in different Mammals, cf. Cuvier, "Leçons d'Anatomie Comparée." 2nd edition, tome i., 1835, p. 177.

179 (ii. 293). On the earlier Skull-theory of Goethe and Oken, cf. Virchow, "Goethe as a Naturalist" ("Goethe als Naturforscher," 1861, p. 103).

180 (ii 295.). Karl Gegenbaur, "The Head-skeleton of Selachii" ("Das Kopfskelet der Selachier"). As the foundation of a study of the head-skeleton of Vertebrates (1872).

181 (ii. 301). Karl Gegenbaur, "On the Archipterygium." —"Jenaische Zeitschrift für Naturwissenschaft," vol. vii. 1873, p. 131.

182 (ii. 304). Gegenbaur, "Researches into the Comparative Anatomy of Vertebrates" ("Untersuchungen zur Vergleichenden Anatomie der Wirbelthiere"). Part I. Carpus and Tarsus (1864). Part II. The shoulder girdle of Vertebrates. Pectoral fins of Fishes (1866).

183 (ii. 305). Charles Martins, "Nouvelle comparaison des membres pelviens et thoraciques chez l'homme et chez les mammifères."—"Memoires de l'Acad. de Montpellier," vol. iii. 1857.

184 (ii. 308). Ossification. Not all bones of the human body are first formed of cartilage. Cf. Gegenbaur, "On Primary and Secondary Bone-formation, with special reference to the Primordial Skull Theory."—"Jenaisch. Zeitschrift für Naturwissenschaft," 1867, vol. iii. p. 54.

185 (ii. 308). Johannes Müller, "Comparative Anatomy of Myxinoides."—"Transactions of the Berlin Academy," 1834–1842.

186 (ii. 314). The Homology of the Primitive Intestine and the two primary germ-layers is the postulate for morphological comparison of the various Metazoa-tribes.

187 (ii. 322). In the Evolution of the Intestine, Amphibia and Ganoids have, by heredity, retained the original Craniota-form more accurately than have Selachii and Osseous Fishes (*Teleostei*).

The palingenetic germination of Selachii has been much altered by kenogenetic adaptations.

188 (ii. 323). On the Homology of Scales and Teeth, cf. Gegenbaur, "Comparative Anatomy" ("Grundriss der vergl. Anatomie," 1874, pp. 426, 582); also Oscar Hertwig, "Jenaische Zeitschrift für Naturwissenschaft," 1874, vol. viii. On the important distinction of homology (morphological resemblance) and Analogy (physiological resemblance), see Gegenbaur, as above, p. 63; also my "Generelle Morphologie," vol. i. p. 313.

189 (ii. 337). Wilhelm Müller, "On the Hypobranchial Groove in Tunicates, and its Presence in the Amphioxus and Cyclostomi."—"Jenaische Zeitschrift für Naturwissenschaft," 1873, vol. viii. p. 327.

190 (ii. 358). The Nerve-muscular Cells of the Hydra throw the earliest light on the simultaneous, phylogenetic differentiation of nerve and muscle tissue. Cf. "Klemenberg, Hydra." Leipzig, 1872.

191 (ii. 383). The germ-history of the human heart accurately reproduces in all essential points its tribal history. This palingenetic reproduction is, however, much contracted in particular points and vitiated by kenogenetic modifications of the original course of evolution, displacements partly in time, partly in place, which are the result of embryonic adaptations.

192 (ii. 383). On the Special Germ-history of the Human vascular system, cf. Kölliker, "History of the Evolution of Man" ("Entwickelungsgeschichte des Menschen." 2nd edition, 1876); also Rathke's excellent work on Ontogeny.

193 (ii. 387). The Homologies of the Primitive Organs, as they are here provisionally described in accordance with the Gastræa-theory (note 24), can only be established by further cooperation between Comparative Anatomy and Ontogeny. Cf. Gegenbaur on Comparative Anatomy ("Grundriss der vergleichenden Anatomie").

194 (ii. 390). The Mechanism of Reproduction. As the functions of reproduction and of heredity, connected with reproduction, are referable to growth, so the former as well as the

latter are finally explicable as the results of the attraction and rejection of homogeneous and heterogeneous particles.

195 (ii. 397). Eduard van Beneden, "De la Distinction originelle du Testicule et de l'Ovaire." Brussels, 1874.

196 (ii. 399). On the Original Hermaphrodite Structure of Vertebrates, cf. Waldeyer, "Ovary and Egg" ("Eierstock und Ei," 1872, p. 152); also Gegenbaur ("Grundriss der vergleichenden Anatomie," 1874, p. 615). On the origin of the eggs from the ovary-epithelium, cf. Pflüger, "On the Ovaries of Mammals and Man" ("Die Eierstöcke der Säugethiere und des Menschen," 1863).

197 (ii. 423). On the special germ-history of the urinary and sexual organs, cf. Kölliker, "History of the Evolution of Man." On the homologies of these organs, see Gegenbaur ("Grundriss der vergleichenden Anatomie," 1874, pp. 610–628).

198 (ii. 448). Wilhelm Wundt, "Lectures on the Human and Animal Mind" ("Vorlesungen über die Menschen- und Thierseele." 1863). W. Wundt, "Outlines of Physiological Psychology" ("Grundzüge der Physiologishen Psychologie," 1874).

199 (ii. 457). On Active (actual) and Latent (preteritial) forces, cf. Hermann Helmholtz, "Interoperation of Natural Forces" ("Wechselwirkung der Naturkräfte," Part II., 1871).

200 (ii. 457). "Anthropology as Part of Zoology."—"Generelle Morphologie," vol. ii. p. 432. "History of Creation," vol. i. 7; vol. ii. 347.

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